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THE ROOTING OF WOODY CUTTINGS CONSIDERED FROM THE STANDPOINT OF ANATOMY.

By W. A. SLEDGE.

INTRODUCTION.

The rooting of a cutting involves the production and maintenance of new root initials in the tissues about the base of the severed shoot. Such roots arise endogenously and frequently, in the striking of a cutting, the new roots grow out through the pad of callus which covers the cut end of the shoot, though the layer most active in callus formation is the phellogen. Examination shows, however, that the roots always arise in the immediate neighbourhood of the vascular cambium. This has been noted by Plett (8), Simon (13) and Van der Lek (7), and the latter calls attention to the fact that in the regeneration of shoots and roots from callus tissue, the former are developed exogenously whilst the root germs are exclusively endogenous. Priestley (9) has summarised the data by saying that " an extended study of propagation in the Dicotyledons leads to the generalisation that the vascular cambium gives rise to root initials only, and the phellogen to new shoot initials." The close anatomical association of root germs with the cambium suggests a corresponding parallelism between the internal factors which govern the initiation and growth of root meristems and those which govern the activity of the vascular cambium.

The vascular cambium normally remains dormant throughout the plant during the winter months. In early spring, following the establishment of favourable internal conditions, the buds are enabled to swell as soon as the external temperature is sufficiently high. As a result of the commencement of growth in the buds, cambial activity is initiated in the meristematic procambial strands of each swelling bud and from each centre spreads gradually down the shoot. The numerous observations which have been recorded as to the time and origin of renewed radial growth in spring indicate that, in Dicotyledons, the recommencement of cambial activity is invariably correlated with the swelling of the buds and is initiated as a result of their growth. Of the older observers, Th. Hartig (1), Strasburger (15) and many others (Hastings (2), Reiche (11)) recorded this correlation, whilst more recently attention has been drawn to it by Knight (6) and Swarbrick (16). The importance of the buds as sources of cambial activity is clearly shown by the effect of disbudding branches during winter, which causes an inhibition of radial growth during the following growing season (Jost (4)).

The cessation of cambial activity in late summer and autumn follows the same course as its initiation in spring, beginning first in the current year's growth and extending from thence down the branches to the base of the tree. Swarbrick has observed the downward cessation of cambial activity in one to five-year-old apple branches and he summarises his observations in the statement " cambial activity ceased in one-year-old shoots about the time elongation growth ceased, but did not cease in the four-year-old branches until a month later." The cessation of cambial activity was found to be associated with a parallel downward wave of starch accumulation.

The close relation which exists between root meristem activity and cambial activity, and between cambial activity and bud growth, intensifies the interest of Van der Lek's results which lead him to conclude that a definite correlation exists between root production and the presence of buds on a cutting. In his investigations on root development in woody cuttings Van der Lek found that the removal of all the buds on cuttings of *Vitis vinifera, Ribes nigrum* and several species of Salix and Populus, had a very unfavourable influence on root formation. With the exception of Vitis, all the types used had pre-formed root initials present in the stem, so that in these types root production did not necessitate a preliminary root initiation. Yet the same correlation between root production and the presence of buds on the cutting was obtained with Vitis, where, in short cuttings bearing one bud, the influence of the bud on rooting was limited principally to the side on which the bud was placed, longitudinal series of roots being formed. This influence often showed itself over a distance of several internodes, a one-sided series of roots occurring in the sector in which the bud was placed. When the bud sprouted strongly in a short cutting a more basal root formation occurred with a stronger development of roots on the side of the bud. By removing the buds root formation was largely inhibited and the few roots formed were restricted to the base. In both Vitis and Ribes nigrum rooting was found to take place better when buds were stunted in development or when their development was inhibited by being plastered with gypsum, than when they were removed. These results were obtained with cuttings which had commenced to grow in spring after the winter rest period. In similar experiments conducted during the summer months, it was found that disbudded cuttings rooted quite as well or even better than normal cuttings.

Van der Lek attributed his results to the downward transmission of hormones liberated from the buds as they became active in spring, these hormones stimulating root growth in the basal end of the cutting. In summer, presumably, the hormones were present in the shoot in sufficient quantity to enable root production to proceed regardless of the removal of buds. But the close relation of the vascular cambium to root production and to the growth of the buds in spring, suggests that the relationship observed by Van der Lek between root production and bud growth in the case of cuttings planted towards the end of the winter rest period, may depend upon the downward spread of cambial activity from the buds which takes place at this time. A possible explanation of the stronger development of roots at a point on a cutting vertically below a young sprout presents itself on the basis of this suggestion. Cambial activity will start first on the stem immediately below the developing shoot and work vertically downwards, and only secondarily will it spread laterally round the stem below the bud and then downwards to form a complete cylinder of new wood. It seems legitimate to assume, therefore, that at the basal end of a woody cutting, that portion of the cambial ring which is situated vertically below an active bud will be the first to commence activity. If root initials are promptly formed, then it follows that the first formed roots will always appear below the growing bud. The retardation of root formation produced by disbudding dormant shoots, a process which prevents the onset of cambial activity, and the absence of this relationship in summer when the cambium is everywhere actively dividing, lend further support to the suggestion that buds influence root production through their effect on cambial activity.

The close inter-relation which apparently exists between the growth of buds, cambium and roots has prompted the work here recorded, which constitutes the results of a close anatomical study of the relation between buds, cambial activity and root production in cuttings.

METHODS AND MATERIAL.

When experiments were first started, cuttings were taken from willow (*Salix Smithiana*), privet, sycamore, apple (Bramley's seedling), Forsythia, Fuchsia, Sambucus, Coleus and Pelargonium. After a few months this range was cut down to a suitable series consisting of privet, Sycamore, apple and Forsythia, the results here recorded being based mainly on observations made on these species.

Every month shoots were taken from each species and these were cut to a node and planted in propagating frames containing sand over leaf mould. The frames stood over warm pipes in a greenhouse. During the winter the cuttings were taken from the previous season's growth and during the summer they were taken from the current year's growth. The state of bud development and the condition of the cambium were examined when the cuttings were taken, and a sufficient number—usually a dozen—were planted, to enable examinations of examples to be made at various intervals of time. The cuttings were preserved in formalin alcohol and cut on a sliding microtome without previous embedding.

DISTRIBUTION OF CAMBIAL ACTIVITY IN CUTTINGS.

In the investigation of the relation of cambial activity at the base of cuttings to the downward spread of activity from the buds, the most valuable data have been obtained from cuttings which were taken during the winter rest period and which became active in the propagating frame. During spring and summer, when growth had recommenced, the uniform activity of the cambium throughout the length of the cutting taken, obscured any correlation which existed between the activity of the cambium in relation to root production and its behaviour in the upper part of the shoot.

Cuttings, therefore, in various stages, which had been planted in the propagating frames during the winter and had sprouted strongly early in the year, were examined carefully at numerous points throughout their length with a view to determining whether root production could only take place after a chain of actively dividing cambial cells had been established between the basal end and the young shoots above. A large number of cuttings have been worked out in this way. Suitable growth stages were not always easily obtained as it frequently occurred that the cutting selected was too far advanced in its growth to show the desired stages, but below is given a detailed account of data obtained from two cuttings of each species, which best illustrate the required observations.

APPLE.

No apple cuttings have been induced to root, though they have nearly always callused well. Cambial activity proceeds as readily in cuttings of apple as in easy rooting species, and all specimens examined in which callus had been formed and leaves produced from the buds showed xylem formation proceeding throughout the length of the cutting.

Fig. 1 represents an apple cutting which had been planted in November and which was examined early in February. No callus was present at the cut end of the shoot, but an annular swelling behind the end indicated the position at which a phellogen had struck across the cortex from the woody cylinder to the epidermal layer and formed a protective cork layer. The cork layer did not extend across the pith. Young leaves were bursting through the terminal bud, and the second lateral bud was slightly swollen. The other buds were dormant.

The annotations to the figure clearly indicate the existence of two independent zones of cambial activity in the shoot. The one had its origin in the bursting terminal bud 1¼ cms. below which, at the point A, there was a thin ring of new wood, one element in depth, broken in a few places where xylem differentiation was incomplete. At the point B, in the middle of the shoot, the stimulating influence of the growing terminal bud had not yet affected the cambium which was here still dormant. In the bottom half of the shoot there was another region of cambial activity, which had its origin at the base of the shoot and decreased in amount in an upward direction. The tendency at the points C and D, where only a small amount of new xylem had been formed, for this new xylem to be associated mainly with the bases of the vascular bundles supplying the buds immediately above, suggests that cambial activity was not unconnected with the buds in the lower half of the stem. But even if these apparently dormant buds had been undergoing internal changes preparatory to active growth, their stage of development was still far behind that which in the normal shoot is associated with the presence below the bud of new and fully lignified xylem elements. The presence, moreover, below a dormant bud at the base of the cutting of a relatively thick and complete ring of new wood, considerably greater in quantity than that formed below the broken terminal bud, clearly indicates that the initiation of cambial activity at the base of the cutting was independent of the buds. The difference in the nature of the activity of the cambium in the proximal and distal parts of the cutting is further emphasised by the fact that in the lower part there was a progressive downward *increase* in the quantity of new wood formed. This was not only evident throughout the region where the cambium was active, but was also plainly visible in the same internode, as is shown by the sections prepared at the two points D and E.

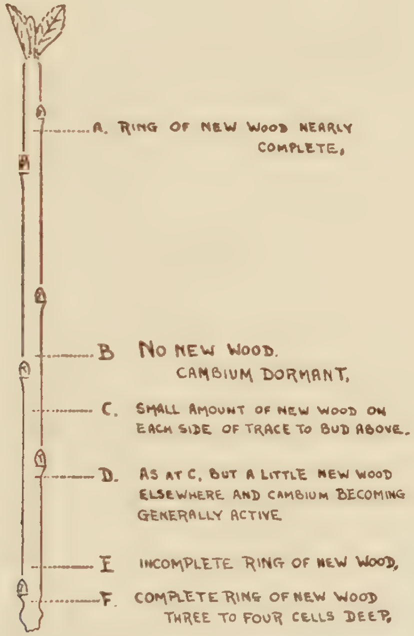
A. RING OF NEW WOOD NEARLY COMPLETE.
B NO NEW WOOD. CAMBIUM DORMANT.
C. SMALL AMOUNT OF NEW WOOD ON EACH SIDE OF TRACE TO BUD ABOVE.
D. AS AT C, BUT A LITTLE NEW WOOD ELSEWHERE AND CAMBIUM BECOMING GENERALLY ACTIVE.
E INCOMPLETE RING OF NEW WOOD,
F. COMPLETE RING OF NEW WOOD THREE TO FOUR CELLS DEEP.

FIG. 1.

Similar results have been obtained with another apple cutting planted at the same time as the one described above and examined early in March. This shoot (Fig. 2) had callused well at the proximal end, and the terminal bud alone had broken. A complete ring of new wood several cells deep was present behind the terminal bud, whilst 3 cms. lower down the ring was thin and broken. Only a few scattered vessels had been formed 3 cms. lower down and this condition held to within 1 cm. of the base of the cutting at which point a definite increase in the amount of wood developed was to be seen. The appearance of the cambium here as compared with its appearance a few centimetres higher up the shoot was also indicative of a more advanced condition towards generally active differentiation. Sections taken through the callused base of the cutting showed that here the cambium was everywhere active and was separated from the old wood by a broad band of new formed tissue, some of which had already lignified to give a zone of new wood, in places twelve cells in depth.

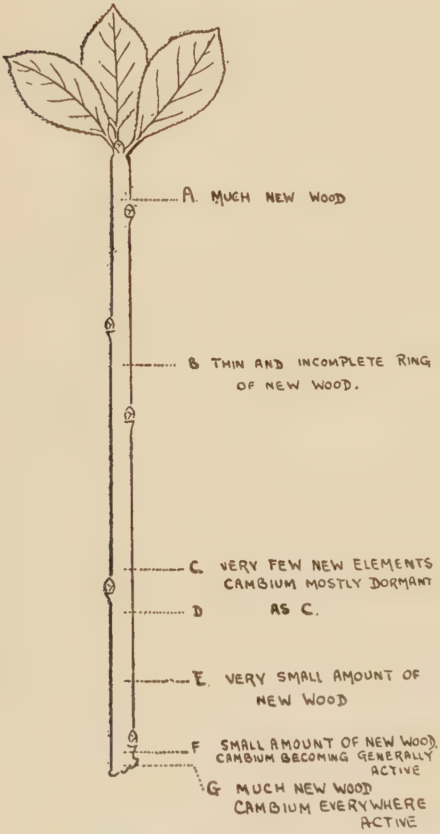
A. MUCH NEW WOOD
B THIN AND INCOMPLETE RING OF NEW WOOD.
C. VERY FEW NEW ELEMENTS CAMBIUM MOSTLY DORMANT
D AS C.
E. VERY SMALL AMOUNT OF NEW WOOD
F SMALL AMOUNT OF NEW WOOD. CAMBIUM BECOMING GENERALLY ACTIVE
G MUCH NEW WOOD CAMBIUM EVERYWHERE ACTIVE

FIG. 2.

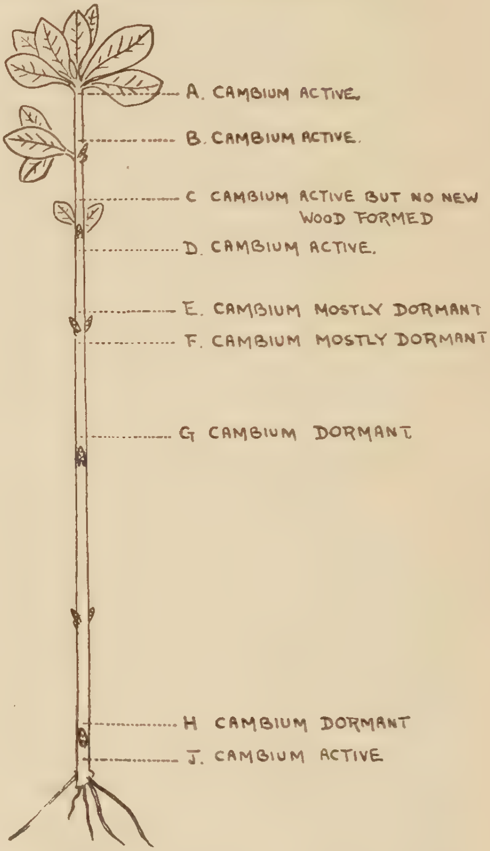
A. CAMBIUM ACTIVE.
B. CAMBIUM ACTIVE.
C CAMBIUM ACTIVE BUT NO NEW WOOD FORMED
D. CAMBIUM ACTIVE.
E. CAMBIUM MOSTLY DORMANT
F. CAMBIUM MOSTLY DORMANT
G CAMBIUM DORMANT
H CAMBIUM DORMANT
J. CAMBIUM ACTIVE

FIG. 3.

Thus the same two opposing gradients of cambial activity are shown in this cutting, though the later period at which the examination was made, and the more advanced growth of the terminal bud, led to the two waves of activity meeting. This is shown by a decrease in the amount of new wood formed, from a maximum below the terminal bud to a minimum at a point about three-quarters of the way down the shoot. Below this point the new wood increased again to a maximum at the callused base.

FORSYTHIA.

Fig. 3 represents a cutting of Forsythia which was planted early in March and had rooted six weeks later. The terminal bud and one bud at each of the next two nodes had burst, and young leaves were present. A complete ring of new wood was established at the point A. The ring was also complete at B, though it was here thinner except at one side of the stele above one of the buds at the node immediately below. Two centimetres below this node the cambium, though not dormant, had produced no new wood. Two fairly large patches of new wood were present at the point D, below one of the buds at the node above. At the bottom of that internode—point E—and immediately below the next node—point F—no new wood was differentiated, though in places the cambium appeared to be in the very early stages of activity. At G, and at H, just above the lowest pairs of buds the cambium had the typically dormant appearance. Immediately below the buds and above the callused end of the cutting—point J—a quantity of new wood had been formed. This was chiefly clustered round the bases of the vascular bundles to the buds above, the cambium appearing dormant in other places.

At the time the set of cuttings which included the one described above were planted many buds were already swelling on the bush from which the cuttings were taken. It may, therefore, be objected that the cambium in the cutting examined had started into activity before the cutting was planted and that the production of roots at the base was directly due to activation of the cambium by the buds just above. This appears less likely when it is recalled that six weeks after planting, the bottom two pairs of buds which had been covered with sand were still unswollen, and no new wood had been differentiated for a distance of 18 cms. in the middle and lower parts of the shoot. The same cambial activity has, moreover, been noticed at the callused base of a Forsythia cutting planted early in February, but which had not produced any roots when examined. This is represented in Fig. 4 and it will be seen that a long dormant zone of cambium intervened between the base and the bursting buds above. Here again, the new xylem developed at the base of the cutting was associated with the buried buds, but in this case cambial activity extended for a short distance above the bottom node.

Thus the two opposing gradients of cambial activity associated with the sprouting buds on the one hand, and with the callused base on the other hand, are recognisable in Forsythia.

PRIVET.

Fig. 5 represents a privet cutting which had been planted late in September and was examined early in March. At this time the terminal bud had burst and several leaves were present. The lateral buds were all dormant. The cutting had callused well and several roots had been produced over a distance of 3.8 cms. behind the callused end. In the upper half of the shoot, a clearly defined downward decrease in the quantity of new wood formed is shown. From a maximum below the sprouting terminal bud, where it was radially three or four cells deep, the new wood decreased in amount to a minimum in the middle region of the shoot where the new wood was only one element in depth. From this region to the base of the cutting an increase in the amount of new wood is shown. Immediately above the callused base of the cutting a thick and complete ring of new wood often twelve cells in depth had been differentiated.

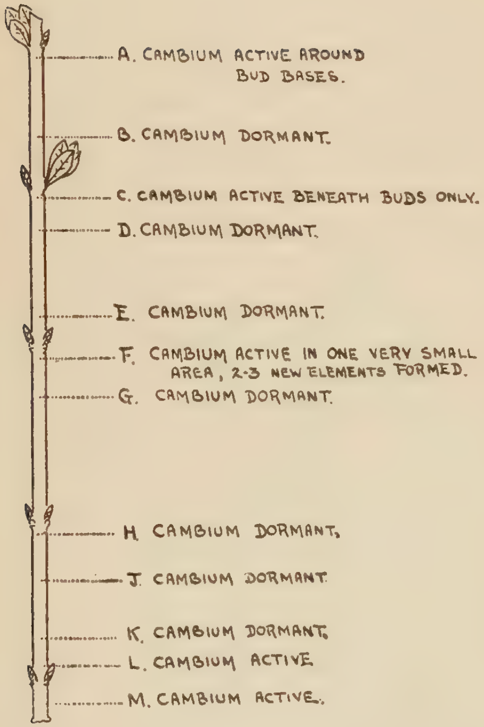
A. CAMBIUM ACTIVE AROUND BUD BASES.
B. CAMBIUM DORMANT.
C. CAMBIUM ACTIVE BENEATH BUDS ONLY.
D. CAMBIUM DORMANT.
E. CAMBIUM DORMANT.
F. CAMBIUM ACTIVE IN ONE VERY SMALL AREA, 2-3 NEW ELEMENTS FORMED.
G. CAMBIUM DORMANT.
H. CAMBIUM DORMANT.
J. CAMBIUM DORMANT.
K. CAMBIUM DORMANT.
L. CAMBIUM ACTIVE.
M. CAMBIUM ACTIVE.

FIG. 4.

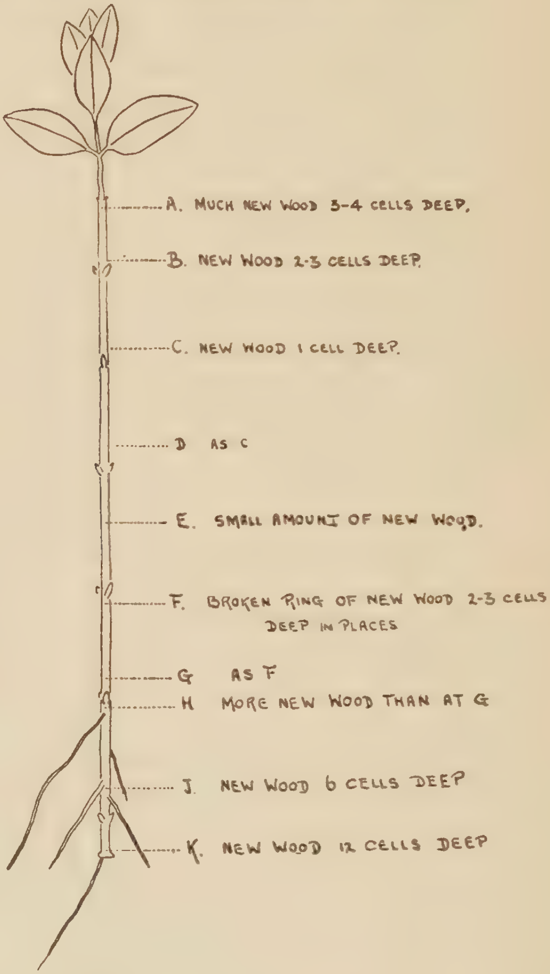
A. MUCH NEW WOOD 3-4 CELLS DEEP.
B. NEW WOOD 2-3 CELLS DEEP.
C. NEW WOOD 1 CELL DEEP.
D AS C
E. SMALL AMOUNT OF NEW WOOD.
F. BROKEN RING OF NEW WOOD 2-3 CELLS DEEP IN PLACES
G AS F
H MORE NEW WOOD THAN AT G
J. NEW WOOD 6 CELLS DEEP
K. NEW WOOD 12 CELLS DEEP

FIG. 5.

In the case of another privet cutting (Fig. 6) which had callused and rooted, and in which only the terminal bud had broken whilst the rest remained dormant, a systematic examination throughout its length gave essentially similar results. In the internode below the terminal bud the amount of new wood produced decreased as the distance from the apex increased. Throughout the next three internodes, a distance of nearly 10 cms. the amount of new wood present was approximately constant, though small in amount. A gradual and constant increase in the quantity of new wood followed for the next 7 cms. At the base of the cutting just above the callus ring, the amount of new wood reached its maximum, and was greatly in excess of the quantity produced beneath the apical bud.

FIG. 5.

Privet Cutting A.

Position on cutting.	Area of total wood and pith.	Area of old wood and pith.	Area of new wood.	Area of new wood expressed as % of that of old wood and pith.
A	7.79	6.43	1.36	21.15
B	8.78	7.60	1.18	15.53
C	13.54	12.23	1.31	10.71
D	16.33	15.07	1.26	8.36
E	20.25	18.95	1.30	6.91
F	6.08	5.84	.24	4.11
G	5.89	5.28	.61	11.55
H	6.75	5.83	.92	15.78
J	8.20	6.82	1.38	20.23
K	10.35	7.30	3.05	41.78

It was necessary to use a higher magnification for the sections A—E and hence the figures for the actual areas of wood are not comparable with those of sections F—K.

FIG. 6.

Privet Cutting B.

Position on cutting.	Area of total wood and pith.	Area of old wood and pith.	Area of new wood.	Area of new wood expressed as % of that of old wood and pith.
A	6.14	5.43	.71	13.07
B	6.74	6.31	.43	6.81
C	11.22	10.78	.44	4.08
D	16.23	15.85	.38	2.03
E	25.36	24.70	.66	2.67
F	25.54	24.58	.96	3.90
G	31.33	29.85	1.48	4.96
H	34.67	32.72	1.95	5.96
J	37.17	34.76	2.43	6.83
K	52.10	42.76	9.34	21.84

Quantitative data have been obtained as to the relative amounts of new and old wood present at the various points of the cuttings at which sections were prepared. The figures were obtained by projecting the sections on to a sheet of paper by means of a projection microscope and measuring the outlined areas of new and old wood by means of a planimeter. The data obtained are tabulated below.

These figures clearly illustrate the existence of a definite gradient in the quantity of new wood formed in the base of the cuttings, the maximum being situated at the callused end of the shoot and the minimum at a point roughly in the middle of the shoot. A similar but opposite gradient extending downwards from a maximum behind the terminal bud is shown. The great excess in the quantity of new wood formed at the base of the cutting as compared with that formed in any other part shows that cambial activity may begin in this region prior to the onset of activity in any other part of the shoot.

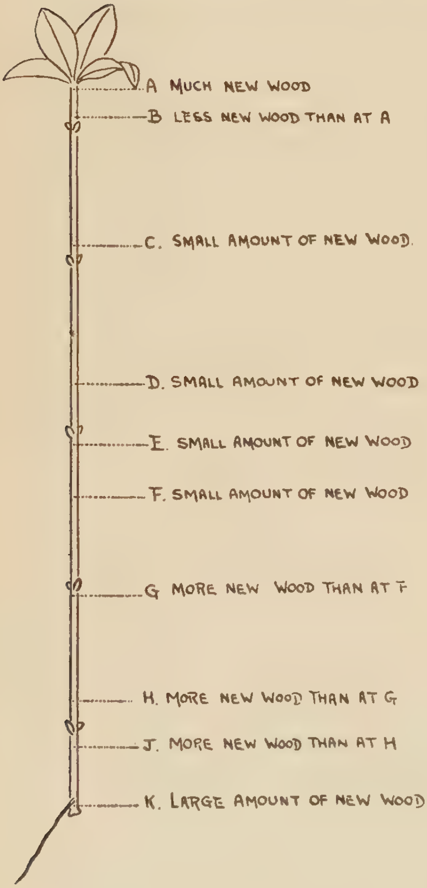
A MUCH NEW WOOD
B LESS NEW WOOD THAN AT A
C. SMALL AMOUNT OF NEW WOOD.
D. SMALL AMOUNT OF NEW WOOD
E. SMALL AMOUNT OF NEW WOOD
F. SMALL AMOUNT OF NEW WOOD
G MORE NEW WOOD THAN AT F
H. MORE NEW WOOD THAN AT G
J. MORE NEW WOOD THAN AT H
K. LARGE AMOUNT OF NEW WOOD

FIG. 6.

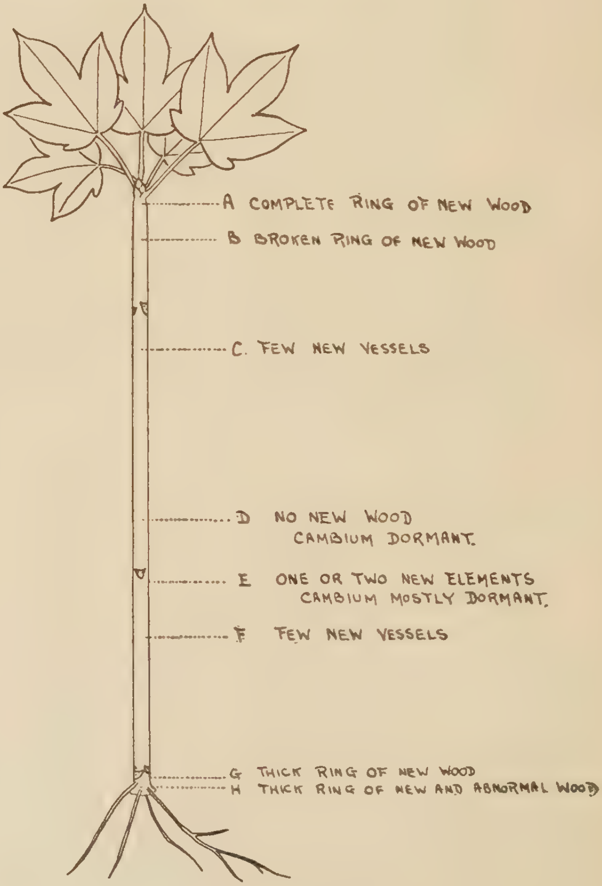
A COMPLETE RING OF NEW WOOD
B BROKEN RING OF NEW WOOD
C. FEW NEW VESSELS
D NO NEW WOOD CAMBIUM DORMANT.
E ONE OR TWO NEW ELEMENTS CAMBIUM MOSTLY DORMANT.
F FEW NEW VESSELS
G THICK RING OF NEW WOOD
H THICK RING OF NEW AND ABNORMAL WOOD

FIG. 7.

SYCAMORE.

The cutting represented in Fig. 7 was planted early in January and was examined late in May. At this time several short roots had been produced and the apical bud was fully open, five young leaves being present. All the lateral buds had been abscissed before growth had commenced.

The annotations to the figure show that in this sycamore cutting as in the cuttings of apple, Forsythia and privet, the same two opposing gradients of cambial activity were present. The basipetal spread of activity initiated in the growing terminal bud decreased from a maximum immediately below the apex of the shoot, to zero at the middle of the shoot, where the cambium was everywhere dormant. At the points E, a small amount of cambial activity was discernible, though for the most part the cambium was dormant, whilst at the base of this cutting this basifugal cambial activity reached a maximum, a thick ring of new wood many cells in depth being present. In the callused base of the cutting at H, an abnormal type of wood referred to below had been formed.

Similar results were obtained with another sycamore cutting. This cutting was taken in mid-June from a shoot of the current year's growth. Roots appeared at the callused base by the middle of October, and a large number were present when it was examined in mid-November. The leaves fell after the cutting had stood in the frame for a week or two, and no buds sprouted. Although the cambium was actively dividing and forming new wood at the time this cutting was planted, a distinct change in the appearance and regularity of a thin ring of wood immediately internal to the cambium marked off the wood produced after the cutting had been planted. Throughout the greater part of the shoot this ring of new wood was only a few elements in depth, and in some places it was not recognisable at all. In the rooting base of the cutting and one centimeter behind the base, however, the ring of new wood was considerably thicker than elsewhere, being ten to twelve cells deep as compared with four to five cells at a point 4 cms. above the base. At the time this cutting was examined the cambium was dormant throughout, and a striking accumulation of starch was noted at the base where all the tissues including the ray initial cells of the cambium were densely packed with granules. In the middle and upper parts of the shoot, starch was scarce or absent.

DISBUDDED CUTTINGS.

A few trials have been conducted upon the rooting of disbudded cuttings of privet and willow planted towards the end of the winter rest period. After a fortnight the buds on the control cuttings had broken or were breaking and many cuttings had rooted. Division of the cambium was proceeding below sprouting buds and at the bases of the shoots. In the disbudded cuttings new buds were regenerated and although no roots had been produced, there were swellings behind the basal ends which indicated the presence of young root germs in the cortex. In these cuttings the cambium was dormant in the region where no new buds had regenerated, but below regenerated buds small patches of new wood had been formed. The cambium was active also at the base of the cuttings. After a month there was little difference between the two sets although the rooting of the normal set was more advanced.

In these trials the regenerated buds were allowed to develop and Van der Lek in his observations on the rooting of disbudded cuttings noted an influence exerted by the regenerated secondary buds. Thus, in *Salix amygdalina*, in which the buds of twelve cuttings had been removed, in six the secondary buds were destroyed besides by piercing them with a thick needle. The root formation in these cuttings was considerably weaker than in the half-dozen in which the secondary buds were not destroyed. Yet buds certainly do not seem essential for root production, and experiment has shown that disbudding proved no hindrance to the start of cambial activity at the base of cuttings where it was well developed in both disbudded and normal examples examined at the same time. Further observations on cambial activity were therefore made on short pieces of internode bearing no buds.

INTERNODAL CUTTINGS.

Plett (8) has carried out extensive investigations on the capacity of isolated herbaceous internodes to regenerate roots and shoots. As a result of his investigations on over 400 species, he found that sixty-seven species gave roots only, eleven gave buds only, and twenty-seven species gave both buds and roots. Regeneration was optimal at the time the parent plant was showing the best vegetative growth, and it took place more rapidly in normally placed pieces than in inverted or horizontal ones. In all the species which regenerated roots, these were strongly localised at the base in whatever position with respect to gravity the internode was placed. He also noted that a displacement of starch occurs in isolated internodes resulting in an accumulation at the basal end. This movement of starch was not influenced by the orientation of the cutting.

Plett's observations do not extend to an investigation of the power of regeneration of internodes taken from plants in which the cambium is dormant, and from the standpoint of this work such information is of great importance. Internodal cuttings were taken therefore during the winter months and placed on damp filter papers in an incubator in which the atmosphere was saturated with water vapour and a constant temperature of 26°C. was maintained. Under these conditions cuttings of apple, beech, sycamore, Sambucus, and Forsythia have readily callused at both cut surfaces within about a week. The callus growth originated as a ring of tissue over the cambium and it continued to grow for another ten to fourteen days. It was invariably less well developed at the distal than at the proximal end of the cutting where in some apple internodes, 2-3 cms. long, it completely covered the severed end of the shoot. Only one of these cuttings has rooted ; an internode of privet producing a short root close behind the basal callus after six weeks in the incubator.

New xylum was plentifully produced at the proximal ends of the internodal cuttings but was not formed at the distal ends. Only in one instance—in an internode of Sambucus—was new xylem detected at the distal end of a cutting. The cambium was mostly dormant in this case but had cut off a few new elements in one place.

Cambial activity was restricted to the immediate base of the cuttings, the maximum upward extension of new wood formation being noticed in Sambucus where new xylem had been formed for a distance of 5 mm. from the callused base. The duration of cambial activity at the base of the internodes was uncertain though the bulk of the new wood formed was differentiated during the period when callus growth was proceeding actively. New wood was noticed at the base of a Sambucus cutting after nine days and approximately twice as much wood was present at the base of another cutting from the same set after five weeks though the continued activity of the cambium at this time was doubtful. In another cutting examined thirteen weeks after the set had been prepared, the amount of new wood formed showed no increase on that in the five-weeks-old internode, and in this cutting the cambium was clearly dormant. Observations on starch distribution have produced results in agreement with those obtained by Plett for similarly prepared cuttings. After three to four weeks in the incubator, starch which was originally plentiful had markedly decreased in amount in all the species, but the remaining starch was localised at the proximal ends of the cuttings and was either absent or very scarce at the distal ends.

WOUND WOOD.

During the examination of cambial activity at the base of apple, sycamore and Sambucus cuttings, an abnormal type of xylem has occasionally been observed. A similar type of abnormal " wound " wood has been seen in cuttings of plums and pears sent by Dr. R. C. Knight from the East Malling Horticultural Research Station, and we have to thank Dr. Knight for first drawing our attention to this anatomical peculiarity of many of these cuttings. This wood is laid down in the region immediately above the proximal callused surface and is characterised by its very uniform composition as seen both in transverse and longitudinal section. With the exception of the medullary ray cells all the elements are practically the same size and shape and are not composed of a mixture of larger vessels and smaller fibres. In transverse section the elements appear rectangular or square shaped. In longitudinal section they are shortly rectangular with square or only slightly oblique cross walls. Fibres have not been detected in " wound " wood, the cells being composed of vessels and tracheids which are mostly reticulately pitted.

In a rooted cutting of sycamore described above, the new wood at the base appeared as a broad and uniform band of cells ten to twelve deep, which were slightly larger than the old tracheids. The walls were only thinly lignified. Very few large vessels were present and where these occurred they abutted directly on the autumn wood of the previous year. A similar type of xylem has been seen in a callused non-rooted cutting of sycamore, the new elements being seldom more than twice as long as broad. In internodal cuttings of sycamore the new wood formed was not markedly atypical.

In some rooted cuttings of Myrobolan B plums examined, the first formed wood elements were very small, rectangular, thick-walled cells, being longer in a tangential than in a radial direction. In their small size and very regular arrangement they had the appearance of cambial cells which had become lignified. Beyond this zone of cells larger ones similar to those described in sycamore had been cut off. Occasional larger vessels were present both in the inner and outer zones of new wood. The general appearance of this xylem was strikingly different from that which had been cut off in the upper part of the shoot.

Whatever significance attaches to the development of abnormal or " wound " wood at the base of cuttings, its formation is clearly of no importance in relation to root production, as no correlation can be traced between the development of " wound " wood and the ability or inability of the cutting to root. Such wood is developed alike in cuttings which root readily or with great difficulty. and in rooted and unrooted cuttings of the same species. Thus in two varieties of pear, rooted cuttings showed the new wood at the base separated into two well defined zones, the inner zone being composed of elements of the " wound " type. The two zones were distinct in longitudinal section, the inner one only extending a short distance up the stem. In unrooted cuttings of both varieties the two zones were again distinct.

FACTORS GOVERNING BASIFUGAL CAMBIAL ACTIVITY.

The data recorded above clearly indicate that cambial activity and root production are not necessarily dependent upon or initiated by the growth or presence of buds. In normal cuttings which start to grow in the propagating frame, two separate and opposed waves of cambial activity associated in one case with the swelling buds and in the other case with the severed end of the shoot, are clearly discernible. Roots may be produced at the base of the cutting at a time when the downward spread of cambial activity from the buds is still very limited in extent, and their production is associated with cambial activity which is proceeding at the base and which spreads basifugally up the cutting.

The activation of the cambium in dormant shoots and its independence of the buds is further shown by the initiation of basifugal radial growth at the proximal end of internodal cuttings.

Normally radial growth invariably proceeds in a basipetal direction, and the spread of cambial activity always in a downward direction in relation to the buds appears to be an inherent characteristic in the organisation of the plant uninfluenced by orientation with respect to gravity. Thus Stewart (14) has noticed that radial increase in diameter in inverted cuttings of Salix is confined to the part of the shoot above (i.e. morphologically below) the buds, the lower part of the shoot undergoing no increase in girth. In the same way, a graft which includes an inverted piece of stem fails to grow properly. In such grafts increase in diameter proceeds readily in the part of the inverted stem which is morphologically below a node, and a good union may be developed between the inverted and the normal scion. The part of the inverted scion which is morphologically above the node, however, withers and dies, an effective union seldom being produced (Rothe, (12)).

Upward spread of cambial activity may occur in the plant, though very few references to such an upward spread are to be found in the literature. Swarbrick has noticed that in a ringed apple shoot new wood formation spreads very slowly upwards to the lower edge of the ring from the first bud below. Knight also noticed a small upward spread of cambial activity from a bud on an apple shoot, in which all the other buds had been removed when dormant.

These instances of a slow, upwardly occurring spread of radial growth are distinct from the pronounced basifugal spread of cambial activity which has its origin at the callused end of a cutting. Cases have been recorded where this activity has resulted in the production of considerably more new wood than has been formed below sprouting buds at the distal ends of the same shoots, and it has been shown also that in apple and privet this type of activity may spread upwards through several internodes. Only one reference to this distinct type of activity has been found, Hartig (1) noticing the same phenomenon as long ago as 1862. Using inverted cuttings of Salix, he noticed that cambial activity still moved from the buds towards the base as in normal shoots, but he also observed that from the proximal callus pad cambial activity proceeds downwards, its progress occurring here, therefore, in a direction opposite to the cambium of the bud base. He therefore inferred that cambial activity in a cutting is not absolutely connected with bud activity. During the course of the present work we have learnt that Dr. R. C. Knight has demonstrated a similar basifugal activity in cuttings of apple, plum, cherry, etc., which have been under examination at East Malling.

It is evident that the basifugal cambial activity which has its origin at the severed end of a cutting is related to the wounding of the shoot. Renewed growth in dormant tissues consequent upon wounding is no new observation. Jost (5) found that in holes bored in the trunks of various trees in late September, callus formation had occurred in mid-October, although general growth had ceased. Janse (3), whilst studying the reaction of plant tissues to injuries, bruises and blows, noticed that such treatment invariably caused a change in the semi-permeability of parenchyma cells, followed by an injection of surrounding air spaces with sap. Priestley and Woffenden (10) also noticed a preliminary injection of the intercellular spaces of cells situated below a cut surface in potato tubers preparatory to the formation of a suberin layer and the development of a phellogen.

Recently, Professor Priestley has put forward a suggestion—as yet unpublished—indicating the significance of air and sap in the intercellular spaces in relation to cambial activity. This suggestion supplies a possible reason for the hitherto unexplained cessation of cambial activity at a time when temperatures are favourable for growth, and photosynthetic conditions are optimal owing to the foliar expansion being at a maximum. During the long summer days, when the leaf area of the tree is at a maximum, transpiration is proceeding rapidly and is in excess of root pressure. A tension is thus set up in the xylem strands supplying the transpiring leaves. In the first year wood, air in the intercellular spaces is prevented by the starch sheath from moving inwards to the xylem, whilst the protoxylem to the inside is surrounded by parenchyma which contains no air spaces. In the older shoots the water tension in the current year's wood results in the withdrawal of water from the older xylem. As a consequence air gradually replaces water, appearing first in the inner layers of the wood and subsequently working outwards. When the air reaches the current year's wood, it is free to move along the intercellular spaces of the medullary rays up to, and past, the zone of cambium cells. In this condition the food supply drawn from the phloem is no longer able to penetrate along the relatively dry walls to the side of the cambium facing the xylem, and xylem differentiation now ceases.

This suggestion, whilst explaining the cause of cessation of cambial activity, also accounts for its downward course, as the state of water deficiency will naturally be reached first where the wood is nearest to the transpiring foliage, and consequently activity will cease first in the current year's shoots and subsequently extend to lower regions of the shoot. The renewed burst of longitudinal and radial growth which frequently takes place in trees during wet and warm summers, lends additional support to the importance of moisture as a governing factor of meristematic activity. In spring, also, an abundant supply of water is present in the tree before cambial activity begins, the air which accumulates in the xylem during the summer being gradually displaced by sap driven up the tree by the continued exudation pressure maintained by the roots.

First hand evidence which confirms the importance of the rôle played by air in regulating meristematic activity has been obtained by observations on the distribution of air in the tissues of dormant and growing shoots. Cross sections of such shoots have been obtained by cutting living material in a sliding microtome, the microtome knife and shoots being bathed in pure glycerine whilst the sections were being cut, and the sections being mounted in pure glycerine. Sections of sycamore, apple and ash were cut in the middle of February at a time when the buds showed no signs of swelling. These all showed an abundance of air in the intercellular spaces of the cortex and pith, and it was very commonly seen penetrating down both multiseriate and uniseriate rays in the phloem and crossing the cambium into the wood. In pear and lilac shoots in which the buds were much swollen, air was absent in the phloem, medullary rays and wood, but common in the cortex and pith. The general impression received from a low power examination of these preparations was that of a perfectly clear zone in the phloem and cambium region in the case of pear and lilac, whilst in sycamore, ash and apple this region was plentifully interspersed with black streaks. These observations have been repeated at later dates and with other species and in all cases a very definite correlation between the state of the buds and the presence or absence of air across the cambium has come to light.

When cuttings are taken, the sap injections of the intercellular spaces around the cambium consequent upon the wounding of the tissues establish precisely those conditions which are normally associated with cambial activity. Whilst it is suggested, however, that sap injection of the intercellular spaces around the cambium, caused by wounding, is a causal factor promoting the onset of cambial activity at the base of a cutting, the failure of the cambium to become active at the distal end of short cuttings where the same conditions of sap injection hold, must remain unexplained. The accumulation of food material at the proximal end of the cutting will undoubtedly constitute a factor favourable to the increased meristematic activity there, though the polarisation of cambial activity cannot be explained on the assumption of limiting food material at the distal end, for the very fact that callus formation proceeds at this end of the cutting shows that food supplied are not inadequate for meristematic needs.

Reconsideration of Van der Lek's Results.

Cambial activity is so closely associated with root meristem activity that its initiation due to wounding at the proximal end of cuttings may alone account for root production in some cases, as in internodal cuttings where regeneration of roots is clearly independent of buds. But the close relationship which has been emphasised by Van der Lek between root production and the presence of buds on a cutting can also be interpreted in terms of basipetal and basifugal cambial activity.

As a result of his observations on root production in disbudded and normal cuttings, Van der Lek concluded that the removal of buds from a shoot had a very unfavourable influence on root production. This influence did not extend to a complete inhibition of root formation, but only to a very marked reduction in the number of roots developed. An examination of his numerous photographs illustrating root development in disbudded and normal cuttings of Ribes, Salix and Populus brings an important difference to light which he does not emphasise in the text. The plates show clearly that whereas in normal cuttings roots have been produced in abundance over a considerable portion of the stem (often to as much as half its length), in the disbudded cuttings the few roots produced are confined to a relatively short region behind the base of the stem. Hence in these cuttings root formation appears very weak by comparison with that in the normal set. In some cases a numerical comparison of the root formation over the short basal region in which roots have developed in the disbudded cuttings, with the root formation over an equal distance about the base of the normal cuttings reveals practically no difference. Usually, however, the roots are better developed in the normal shoots than in the disbudded ones.

A consideration of the state of cambial activity in the two sets of cuttings provides a ready interpretation of these results. In the normal cuttings the buds sprout and cambial activity spreads downwards throughout the shoots. The cuttings were illuminated to the base as they were placed in tall glass cylinders with their bases in water and their upper parts either enclosed in the cylinders or projecting through corks, and so the renewal of cambial activity may have been more rapid due to the swelling of the buds on the lower parts of the stem, though the cuttings illustrated do not show any sprouts developed from the lower buds. In any case, the state of bud development at the distal ends of the cuttings amply justifies the assumption that the cambium was active throughout the lengths of the shoots at the time the photographs were taken. In this condition, then, all the root germs are able to develop, and so abundant root production occurs.

In the disbudded cuttings, on the other hand, there is no basipetal spread of cambial activity, owing to the removal of the buds, whence such activity has its source. At the base of the cuttings, however, a wound-initiated basifugal activity of the cambium will begin and spread for a short distance up the stem. Hence in these cuttings only those root germs which come within the influence of this restricted zone of cambial activity will be able to develop.

Experiments performed in the course of this work dealing with root production in normal and disbudded cuttings of willow and privet, showed that after two months no detectable difference existed between the two sets. The strong root production which took place in the disbudded cuttings is here correlated with the development of adventitious buds and the consequent initiation of basipetal cambial activity. In Van der Lek's work the photographs showing well rooted normal cuttings and poorly rooted disbudded cuttings were all taken either two or three weeks after the experiment was started. At this time secondary buds had not developed, or were only beginning to develop, and hence the cambium was still inactive throughout the greater parts of the cuttings. He observed, however, that when the secondary buds were allowed to develop on willow cuttings, that these cuttings rooted better than similarly disbudded cuttings in which the secondary buds were killed as they developed.

In some further experiments on the rooting of short internodes of Vitis bearing one bud, Van der Lek found that longitudinal series of roots were produced on the side of the stem below the bud. He also noted that " after removing the bud, root formation only took place at the base, or as least remained limited to that point for a long time." In the observations recorded above on the development of cambial activity in internodal cuttings, attention was drawn to the fact that in such short pieces of stem cambial activity was restricted to the base, the maximum upward spread of activity being noted in Sambucus where new wood had been formed for a distance of only half a centimeter back from the proximal callused end of the stem. Thus, in short cuttings, the upward spread of cambial activity from the base is far less well developed than in cuttings consisting of several internodes and nodes. This fact may be held to account for Van der Lek's observation that in short disbudded cuttings of Vitis, root production was strictly limited to the base of the stem. The smaller production of roots in such cuttings is probably correlated with the small supplies of available food material, and where sprouting buds were present on the cuttings, the general activity of the cambium enabled root production to proceed wherever an adequate food supply was forthcoming, and hence a series of roots was formed below the bud.

Probably little significance attaches to Van der Lek's experiments in which, although buds were covered with gypsum to inhibit their development, the root production closely approximated to that in normal cuttings. It is unlikely that this treatment caused the cambium in the stem to remain dormant as some swelling of the buds probably always occurred ; indeed he admits that unless it were strong enough the gypsum was burst by the swelling of the buds.

Finally it must be recalled that Van der Lek's results were obtained only with cuttings, which had begun to grow after the winter rest period. From the present standpoint, therefore, the significance of his observation that in similar experiments conducted during the summer months disbudded cuttings rooted quite as well as normal cuttings, is very clear.

The results arising out of Van der Lek's work are thus so closely correlated with the known facts as to cambial behaviour that, though further anatomical observations can alone prove whether this interpretation will hold, it is quite unnecessary to postulate the existence and action of hormones as responsible for the results obtained.

SUMMARY.

The downward movement of cambial activity from the buds in spring recorded by many workers has been observed in shoots of apple, Forsythia, privet and sycamore.

An explanation of the correlation observed by Van der Lek between root formation and the presence of buds on a cutting has been sought for in terms of the downward spread of cambial activity from the buds, and the origin of adventitious roots from the cambial layer.

In normal cuttings taken from dormant shoots, which started into growth in the propagating frame, cambial activity commences at the base and roots may be formed prior to the downward spread of activity from the buds reaching the proximal end of the cutting. The activity at the base of the cutting is well developed alike in rooting and non-rooting types, and is remarkable on account of its ready propagation in a basifugal direction. Thus, two separate and opposed gradients of cambial activity have been detected in the cuttings examined, the one associated with the swelling buds, and the other with the severed end of the shoot.

The activation of the cambium in dormant shoots and its independence of the buds is shown by the initiation in all species examined of radial growth at the proximal end of internodal cuttings. Here cambial activity occurs only over a very limited extent about the base of the internode and only once has it been detected at the distal end, where it was independently initiated. In one instance roots have been obtained from an internodal cutting.

Some observations are recorded upon the development of an abnormal type of wood at the base of cuttings. Though the cause of its development is unknown the fact that it occurs in rooting and non-rooting types, and may or may not be formed in cuttings of the same species, does not point to its having any significance from the standpoint of the ability of a cutting to produce roots.

Observations on the presence or absence of air across the cambial layer in stems of dormant and growing shoots support the suggested importance in relation to meristematic activity of the distribution of air in the intercellular spaces of the shoot. It is, therefore, suggested that a wound stimulus, functioning through the injection of the intercellular spaces of the region around the cambium, plays an important rôle in the initiation of basifugal cambial activity. But the failure of cambial activity at the distal end of cuttings, which cannot always be accounted for by the basipetal transport of food which takes place, points to the existence of another unknown factor which is also involved. The

restriction of cambial activity to the proximal end of internodal cuttings accounts for the polarised root production always associated with this end.

An interpretation of Van der Lek's results is advanced in terms of basipetal and basifugal cambial activity.

The Author wishes to express his most sincere thanks to Professor J. H. Priestley, under whose supervision this work was carried out, for his constant help and advice ; and also to the Department of Scientific and Industrial Research, for a grant of maintenance. He is also very grateful to Dr. R. C. Knight for valuable advice, given at an early stage of the work, upon practical points connected with accepted methods of making hardwood cuttings.

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EXPERIMENTS ON THE MANURING OF FRUIT TREES.

III. THE EFFECTS OF DEFICIENCIES OF POTASSIUM, CALCIUM, AND MAGNESIUM, RESPECTIVELY, ON THE CONTENTS OF THESE ELEMENTS, AND OF PHOSPHORUS IN THE SHOOT AND TRUNK REGIONS OF APPLE TREES.

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In two previous papers of this series (5), some nutritional experiments on apple trees, gooseberry and black currant bushes and raspberry and strawberry plants in sand cultures were described.

The results reported related to the effects produced on shoot growth, foliage characters, blossoming, fruiting, defoliation phenomena and root characters by deficiencies of the various major " essential " elements and by various ratios of $\frac{\text{Nitrogen}}{\text{Potassium}}$ and $\frac{\text{Potassium}}{\text{Magnesium}}$ in the diets of the plants. It was shown in those experiments that a deficiency of each of the elements considered produced well-defined effects and that the effects in each case were readily distinguishable and could be used by an experienced observer for diagnostic purposes.

In carrying out the experiments, it was not possible to make chemical studies on the plants utilised in the work but, since that time, opportunities for such work have occurred and this branch of the investigations has been pursued.

In the experiments described in the present paper, the effects of deficiencies of potassium, calcium and magnesium on the contents of these elements and of phosphorus in the shoot and trunk regions of young apple trees have been examined. The primary objects of the work have been to ascertain the extent to which deficiencies of the three elements are reflected in the mineral contents of the various portions of the trees examined and to obtain information regarding methods of sampling trees in chemical studies.

The results reported show that deficiences of the three elements considered are reflected in the composition of the mineral portions of the leaves and of the bark and wood of both the shoot and main stem portions of the trees. They also show that, in investigations of this type, it is necessary to analyse bark and wood separately, since they differ markedly in composition, and especially where materials of different ages are concerned, when the proportions of bark to wood differ widely.

In addition to the above results, it has been possible in these experiments to distinguish more clearly the leaf characters resulting from calcium deficiency and it was found that the variety of apple used appeared to be much more drastically affected by magnesium starvation than any variety used hitherto while potassium deficiency resulted in much larger shoot growth than in the complete nutrient series, a result not in accord with our previous experience.

Of the previous investigations which have been reported relating to the problems under consideration, mention may be made of the work of Butler, Smith and Curry (1) who examined the distribution of certain reserve materials and ash constituents in the various portions of apple trees, of Reed and Haas (3) who have studied the effects of certain nutrient treatments on citrus trees in sand and soil cultures, of Tufts (4) who has investigated methods of sampling shoots of peach, pear and apple trees in relation to the distribution of reserve materials and of the writer in investigations on chlorosis (6, 7) and on the effects of manurial treatments on the composition of gooseberry bushes (8).

EXPERIMENTAL.

The trees employed in the investigation consisted of eighty maiden apple trees, variety Stirling Castle, all worked on Malling Type I rootstock. They were divided into four groups of twenty each for the treatments " complete nutrient," " calcium omitted," " magnesium omitted " and " potassium omitted," and were planted during January, 1926, in a good quality quartz sand —99.5 per cent. insoluble in boiling hydrochloric acid—contained in 10 inch unglazed but previously waxed plant pots. Each pot contained 10 kilos. of sand. The pots were fitted as previously described (5), with the exception that dome-shaped earthenware covers, previously waxed and each with a hole 2 inches in diameter through the centre, were used to cover the tops of the pots vice tarpaulin covers. This new type of cover was found to be more efficient than the old one both as a means of keeping out the rain and of preserving an even, low temperature in the sand medium.

The culture solution used as the " complete " nutrient solution differed from that originally used (5) in that it contained approximately three times as much potassium and magnesium, twice as much calcium and no sodium. Details of its composition are as follows :—

	gms.
Potassium Nitrate	8.0
Potassium Chloride	1.0
Di-potassium mono-hydrogen phosphate ($K_2H\ PO_4$)	1.0
Calcium Sulphate	2.0
Magnesium Sulphate $7H_2O$	3.0
Ferric Chloride	0.4
Rain Water	to 1 litre.

One litre of the above solution was diluted with 9 litres of rain water previous to application.

The concentrations of certain of the elements as parts per million in the solution as applied are as follows: nitrogen 112, potassium 385, calcium 60, magnesium 30, phosphorus 17, iron 14.

In order to derive the various "omission" solutions from the "complete" solution, the salt (or salts) containing the element to be omitted was replaced by an equivalent amount of the corresponding sodium salt.

It should be pointed out that the "complete" solution is regarded as being definitely high in potassium and it seems possible that, for the particular variety of apple used, a solution lower in potassium would be more suitable.

The technique of tending the cultures was as followed in the previous work. Aphides were controlled by winter washing with a tar-distillate wash and removing by hand or by means of a camel hair brush any pests which appeared during the growing season.

At planting all fibrous roots were removed from the trees and the stems were headed back to a length of approximately 20 inches. The first applications of the nutrient solutions were given on February 25th.

Samples of material for analytical purposes were obtained in the following way. The trees receiving each treatment were divided into two groups, one group being designated the "Summer Pruned Group" and the other the "Winter Pruned Group." In the "complete" nutrient, potassium omitted, and calcium omitted series, the summer pruned group comprised five trees and the winter pruned group fifteen trees, but in the magnesium omitted series both groups contained ten trees, as it was found in this last series that five trees were too few to supply the analytical material required from them.

The summer pruned trees were used to provide samples of shoots, comprising leaves and stems representative of the active growing season, and the winter pruned groups to supply samples of shoots during the dormant period.

It was proposed originally to take the former samples in each season at the time when any one series should show signs of developing serious breakdown of the leaves and this plan was followed in the first two seasons, but, in the third, the magnesium omitted series collapsed at too early a date to obtain samples large enough from the summer pruned groups and thus on this occasion this series was treated in a special way, leaf samples only being taken at this early date, but from both the summer and winter pruned groups, and the remaining three series were sampled in the usual way at a later date when breakdown symptoms had commenced to show to a slight extent in all of them. The samples from the winter pruned trees were due to be taken when the trees appeared to be in a dormant condition and this procedure was adhered to in all seasons.

The summer pruned trees also received a winter pruning at the same time as the winter pruned samples were taken but the shoots removed on such occasions, which comprised all the new growth since the summer pruning, were not utilised for analytical purposes.

The shoots employed for the analyses in all cases comprised the whole of the shoot growth made during the season prior to the sampling operation, the growths being cut off at the points of junction with the main stem in each case.

In the summer pruned series all leaves attached to the severed shoots were used in the analyses but several leaves were lost each year from wind damage prior to sampling.

Previous to taking all samples, the sand in the pots was brought to maximum moisture content and all samples for comparison were taken within the space of a few minutes.

The summer shoots were divided into two parts, laminæ of leaves and stems plus petioles and the winter shoots into bark and wood.

The portions of the main stems of the trees above the stock and scion unions were analysed in bark and wood samples at the end of the experiment.

Throughout the duration of the experiment, detailed observations were made on the growth features of the trees.

RESULTS.

Growth Features.

Complete Nutrient Series.—All trees made good growth during 1926. The foliage was of excellent quality throughout the season, but small areas of dead tissue in the form of spots and patches were present on the leaves to a slight extent from July 11th. Defoliation proceeded rapidly from October 26th.

The summer pruned series, subsequent to pruning, developed healthy shoots, which carried healthy foliage and grew to lengths of 2 to 3 inches.

During 1927 the amount of shoot growth made by the winter pruned series was approximately twice as great as in 1926. The foliage was generally of good quality but dead patches of tissue were apparent to a small extent from June 22nd. Around July 10th, serious defoliation occurred from very high winds, in some cases shoots becoming 50 per cent. defoliated. Autumn defoliation proceeded rapidly from the beginning of October.

The growth made by the summer pruned series after pruning was similar to 1926 and the foliage borne was healthy.

In 1928 shoot growth was smaller than in the previous season. The foliage remained of excellent quality until June 11th when some wind damage occurred. This was followed by an aphis attack and, in spite of much attention, by July 15th, the pest had caused serious defoliation in some trees. During this period dead patches on the foliage became fairly numerous and the most seriously affected leaves in some cases were shed. Autumn defoliation proceeded rapidly during the early part of October. During the latter part of the season, approximately 20 per cent. of the shoots showed dead tips.

The summer pruned series made practically no shoot elongation subsequent to pruning but carried healthy foliage until the end of the season.

Potassium Omitted Series.—The trees made good growth during 1926, being similar to that in the complete nutrient series, and carried excellent foliage throughout most of the season. One tree developed severe leaf scorch about September 24th and others showed the trouble to a slight extent during October. Defoliation occurred a little later than in the complete nutrient series.

The growth features in the summer pruned group were similar to those in the corresponding group in the complete nutrient series.

During the second season, the winter pruned trees made considerably larger shoot growth than in the complete nutrient series. The foliage until early July was of excellent appearance but, from this time, leaf scorch developed and, on July 10th, two trees showed severe scorch and five trees slight amounts. It was evident that the gales at this period caused much less defoliation than in the other series. (See also 1928 notes.) All trees showed severe scorch and had lost approximately 20 per cent. of their foliage by September 12th whereas, on this date, in the complete nutrient series, defoliation amounted to approximately 50 per cent. It was notable that defoliation was proceeding generally in the direction from the tips of the shoots downwards towards the crotch, in contrast to the other series where defoliation proceeded in the opposite direction. This method of defoliating in cases of potassium deficiency is common and is a useful diagnostic feature. Many dead tips were noted in the shoots from September 12th and, at the end of the season, it was found that, of a total of seventy-four shoots, twenty-two showed dead tips. This did not occur in any other series during 1927. General defoliation of this series occurred at a later date than in the complete nutrient series, defoliation varying from 40 per cent. to 80 per cent. on October 6th in the series whereas, on that date, the trees in the complete nutrient series mostly retained only tip rosettes of leaves.

The growth features of the summer pruned series were similar to those in the complete nutrient series.

In 1928, the trees in this series again made larger shoot growth than in the complete nutrient series, the shoot growth being practically the same as in 1927. The growth features were similar to those in 1927, the foliage remaining healthy until leaf scorch appeared in early July. The gales in June did not cause much damage to the foliage but aphis damage in July caused rather serious effects on some trees. All trees showed severe leaf scorch by the end of August but there were never any signs of spots or patches of dead tissue on the leaves, such as became serious in the other series, especially in the calcium and magnesium omitted series. Indeed it seems highly probable that the spotting and patching effects are related to high potassium feeding. Defoliation occurred later than in the other three series, the trees retaining 50 per cent. of their foliage on October 14th whereas, in the other series, only tip rosettes were retained. The direction of defoliation was again from tips downwards. Of eighty-four shoots, fifteen showed dead tips after defoliation.

The summer pruned trees in this series were the only ones to make any shoot growth after the summer pruning, shoot lengths from 2 to 6 inches being made, whilst the foliage carried on these was as healthy as in the complete nutrient series.

Calcium Omitted Series.—The shoot growth made by the trees in this series during 1926 was somewhat larger than in the complete nutrient series and it was notable that the leaves were larger in size. The quality of the foliage was also similar to that in the complete nutrient series but patches of dead tissue were slightly more frequent in the calcium omitted series. Defoliation phenomena were similar in the two series, as also was the behaviour of the trees in the summer pruned groups.

In 1927, shoot growth was again definitely larger than in the complete nutrient series, although somewhat smaller than in the potassium omitted series. The leaves were again observed to be rather larger in size than in the complete nutrient series from about the middle of June. Dead patches, both near the centres and margins of the leaves, were observed from June 3rd and, by July 10th, these breakdown patches were very prevalent. About that time, severe defoliation occurred from the high winds and, from then to the end of the season, the trees behaved as in the complete nutrient series.

The trees in the summer pruned group, subsequent to pruning, were similar to those in the complete nutrient group but, from September 12th, the leaves showed dead patches.

In the last season, shoot growth was also slightly larger than in the complete nutrient series and throughout the season the general growth characters in the two series were similar, excepting that, in the calcium omitted series, larger leaves were developed and from July 4th dead patches on the leaves were much more prevalent. By August 30th, breakdown was very severe and the foliage was in poor condition. Detailed notes were made on the forms of breakdown on that date when three main forms were distinguished.

(*a*) The typical centre "blotch," as previously described in connection with magnesium deficiency (5).

(*b*) Marginal effects resembling leaf scorch, in which cases the texture of the affected portions appeared to be very thin and brittle.

(*c*) Irregularly shaped patches, extending either from the tips or from points on the margins.

Defoliation occurred simultaneously with the complete nutrient series. After defoliation it was found that ten shoots of a total seventy-eight showed dead tips.

The summer pruned trees made very poor growth after pruning. They failed to make any shoots, only rosettes of leaves of very thin delicate texture being developed. These showed severe breakdown by August 20th and were all dying off on October 14th, at which time the foliage in the complete nutrient and potassium deficient series appeared quite healthy.

Magnesium Omitted Series.—The treatment given to this series produced very drastic effects on shoot growth and foliage characters from an early date.

In the first season, shoot growth and foliage characters were very similar to those in the calcium omitted series until July 29th, both shoots and leaves tending to be large. By June 28th, patches of dead tissue began to appear on the older leaves and, by July 11th, the affected leaves commenced to be shed. The extent of the breakdown was very severe by July 29th and, from this date, defoliation proceeded rapidly. On September 24th, only tip rosettes were retained.

Shoot growth was greatly restricted in the summer pruned group after pruning and, in early October, the foliage showed much patch dying.

In 1927, shoot growth was very poor and the foliage was in poor condition from an early date. The first breakdown was noted on May 26th and, by June 3rd, the leaves were notably pale and showed much dying in patches, both near the centres and margins of the leaves. By June 22nd, the foliage was in very poor condition and many shoots were approximately 50 per cent. to 60 per cent. defoliated, the younger leaves having a somewhat chlorotic appearance. Only tip rosettes and occasional older leaves in poor condition were retained on July 10th.

The summer pruned group produced practically no shoot growths after pruning and the leaves which developed were pale green in colour, and thin and delicate in texture. They developed breakdown symptoms at an early stage and many were shed by September 12th.

In the last season, many of the trees in this series were unable to make any appreciable amount of healthy growth. On May 10th, it was observed that shoot growth was much behind that in the other series and, in many cases, only rosettes had been formed. By May 25th, breakdown of foliage was very severe and, within the course of the following week, much defoliation took place. The leaves were often slightly chlorotic, the texture was very thin and delicate, and breakdown took the form of dead patches as described under the calcium omitted series.

In view of the condition of the trees, samples of foliage were collected for analysis from all except one tree on June 4th. During the remainder of the season, the trees continued to develop successive series of leaves which usually collapsed and were shed when they were about 1 inch in length.

In connection with the above observations, it seems necessary to point out that the types of leaf breakdown developed in the three series complete nutrient, calcium omitted and magnesium omitted were similar in appearance, although the extent of the breakdown in the last series was much greater than in the other two and was also greater in the calcium omitted series than in the complete nutrient series. The development of the dead patches along the margins in some cases is of interest, as in previous work, using the varieties Cox Orange Pippin, Allington and Worcester, the breakdown due to magnesium deficiency has been developed much more definitely in the central portions of the leaves as " Blotch." In an experiment still in progress, using the variety Bramley's Seedling, it has also been observed that the breakdown symptoms for the treatments calcium omitted and magnesium omitted are similar, but that the extent of breakdown in the case of the magnesium omitted series is much more serious than in the calcium omitted series while in the latter series a much larger proportion of the patches occur at or near the leaf margins.

CHEMICAL DATA.

The chemical data are summarised in Tables I. to IV.

In Tables I a. and I b., data relating to the summer prunings are presented for three seasons. It should be noted that the data for the leaves in the magnesium omitted series for the third season were obtained from trees of both summer and winter pruned series. Further, there are no data for this series in Table I b. for that season as the shoots were too small to provide material for analysis of the stems and petioles. It was not possible to separate the stem portions of the samples into bark and wood samples in the summer pruned series owing to lack of material. As will be seen from the data in Tables II. and III. such procedure is extremely desirable in investigations of this type.

The data obtained on the shoots in the winter pruned series are available only for the second and third seasons owing to the unfortunate loss of the material in the first season. There was no material obtainable in the third season from the magnesium omitted series.

The data in Table III. were obtained from the main stem portions extending from the crotch to a point about 1½ inches above the union of the stock and scion.

The percentages of the ash constituents are shown both as percentages of ash and of dry matter in order to show the necessity of considering the contents

TABLE I a.

Summer Pruned Series—Leaves.

Series.	Dates of Sampling.	Fresh wt. taken (gms.)	Dry matter in fresh wt. %	Ash in dry matter. %	Ash constituents as % of Ash.				Ash constituents as % of Dry Matter.			
					CaO.	MgO.	K_2O.	P_2O_5	CaO	MgO.	K_2O.	P_2O_5.
Complete Nutrient ..	29/7/26	50.4	44.14	6.89	13.15	4.65	46.73	5.68	0.8969	0.3172	3.187	0.3874
	13/6/27	99.4	33.15	8.55	11.42	2.91	45.44	4.62	0.9766	0.2488	3.886	0.3950
	7/7/28	74.9	33.92	8.91	8.20	3.09	45.40	5.42	0.7307	0.2754	4.046	0.4829
Potassium Omitted ..	29/7/26	56.7	40.23	5.28	24.01	9.13	20.90	8.58	1.268	0.4820	1.104	0.4530
	13/6/27	95.6	34.89	6.43	22.48	3.04	22.49	7.12	1.445	0.1954	1.445	0.4578
	7/7/28	66.6	38.00	7.50	23.26	9.16	10.58	5.89	1.745	0.6871	0.7936	0.4418
Calcium Omitted ..	29/7/26	67.5	37.87	6.95	11.33	4.40	47.96	6.34	0.7874	0.3059	3.333	0.4407
	13/6/27	87.6	33.11	9.41	8.93	2.85	45.33	4.44	0.8405	0.2681	4.266	0.4178
	7/7/28	74.9	36.64	6.88	7.13	3.72	49.26	3.40	0.4906	0.2560	3.389	0.2340
Magnesium Omitted ..	29/7/26	84.1	38.23	7.57	12.01	2.05	44.01	5.66	0.9090	0.1552	3.332	0.4285
	13/6/27	73.1	32.63	10.23	9.91	1.02	46.89	5.44	1.014	0.1043	4.795	0.5564
	*4/6/28	—	—	11.25	9.69	0.96	44.86	6.29	1.090	0.1080	5.047	0.7053

* Leaves from winter pruned trees also this occasion.

Table I b.

Summer Pruned Series—Stems and Petioles.

Series.	Dates of Sampling.	Fresh wt. taken (gms.)	Dry matter in fresh wt. %	Ash in dry matter. %	Ash constituents as % of Ash.				Ash constituents as % of Dry Matter.			
					CaO.	MgO.	K_2O.	P_2O_5	CaO	MgO.	K_2O.	P_2O_5.
Complete Nutrient ..	29/7/26	42.2	33.80	6.11	21.68	6.52	30.13	4.58	1.324	0.382	1.841	0.280
	13/6/27	41.1	31.06	8.07	18.52	5.90	34.95	3.67	1.495	0.476	2.820	0.296
	7/7/28	51.2	35.02	6.50	14.45	4.90	37.25	5.42	0.939	0.319	2.421	0.352
Potassium Omitted ..	29/7/26	36.4	36.67	5.10	27.85	7.98	17.69	6.57	1.420	0.407	0.902	0.335
	13/6/27	45.2	32.22	6.21	27.27	8.28	17.56	4.14	1.693	0.514	1.090	0.257
	7/7/28	48.8	30.00	5.26	27.95	8.47	13.48	6.62	1.470	0.446	0.709	0.348
Calcium Omitted ..	29/7/26	56.1	29.59	5.78	19.34	6.08	41.74	5.24	1.118	0.351	2.412	0.303
	13/6/27	32.2	30.68	8.61	15.30	6.37	37.37	1.85	1.317	0.548	3.218	0.159
	7/7/28	43.5	36.93	6.47	13.67	5.56	39.68	5.49	0.885	0.360	2.567	0.355
Magnesium Omitted ..	29/7/26	61.0	38.23	7.00	26.78	2.80	30.80	4.26	1.873	0.196	2.156	—
	13/6/27	25.6	30.14	10.29	24.46	2.57	30.15	1.70	2.517	0.264	3.101	0.239

TABLE II.

Winter Pruned Series—Shoots as Bark and Wood.

Series.	Dates of Sampling.	Fresh wt. taken (gms.)	Dry matter in fresh wt. %	Ash in dry matter. %	Ash constituents as % of Ash.				Ash constituents as % of Dry Matter.			
					CaO.	MgO.	K_2O.	P_2O_5	CaO	MgO.	K_2O.	P_2O_5.
BARK.												
Complete Nutrient ..	9/1/28	146.6	41.14	5.96	17.58	4.80	35.61	7.04	1.047	0.286	2.121	0.420
	3/12/28	110.5	41.61	6.19	20.30	4.37	37.83	7.09	1.257	0.271	2.342	0.439
Potassium Omitted ..	9/1/28	189.2	44.62	5.96	25.71	8.16	18.70	10.29	1.532	0.486	1.114	0.613
	3/12/28	192.0	46.19	5.57	29.86	8.29	16.37	10.19	1.663	0.462	0.912	0.567
Calcium Omitted ..	9/1/28	182.8	41.33	5.49	12.94	5.95	40.13	8.28	0.7106	0.327	2.203	0.455
	3/12/28	138.2	43.75	5.47	13.03	5.99	39.28	8.59	0.7127	0.328	2.149	0.470
Magnesium Omitted ..	9/1/28	29.4	37.60	8.00	24.84	1.82	27.50	5.89	1.987	0.146	2.200	0.471
WOOD.												
Complete Nutrient ..	9/1/28	132.4	49.82	2.21	11.97	5.59	37.63	11.97	0.2645	0.1235	0.8316	0.2645
	3/12/28	181.6	48.89	2.28	11.51	5.41	38.68	12.71	0.2852	0.1233	0.8818	0.2897
Potassium Omitted ..	9/1/28	143.0	53.20	1.45	19.55	9.66	19.88	20.13	0.2776	0.1371	0.2823	0.2859
	3/12/28	148.7	53.96	1.51	23.73	8.58	18.61	22.23	0.3583	0.1296	0.2809	0.3357
Calcium Omitted ..	9/1/28	137.2	50.36	2.06	7.32	6.71	44.82	12.84	0.1508	0.1382	0.9234	0.2645
	3/12/28	96.2	52.58	1.88	9.09	6.62	39.43	15.31	0.1709	0.1242	0.4513	0.2878
Magnesium Omitted ..	9/1/28	20.6	44.50	2.68	14.07	2.60	34.10	12.28	0.3770	0.0697	0.9139	0.3291

TABLE III.

Main Stems—Bark and Wood. Sampled 3/12/28.

Material and Series.	Fresh wt. taken (gms.)	Dry matter in fresh wt. %	Ash in dry matter. %	Ash constituents as % of Ash.				Ash constituents as % of Dry Matter.			
				CaO.	MgO	K_2O.	P_2O_5	CaO.	MgO.	K_2O.	P_2O_5.
SUMMER PRUNED TREES.											
BARK.											
Complete Nutrient	51.0	40.41	6.23	17.02	4.32	34.36	6.49	1.060	0.2692	2.141	0.4042
Potassium Omitted	37.7	43.53	5.01	32.16	5.74	6.47	7.87	1.611	0.2876	0.3167	0.3943
Calcium Omitted	48.1	36.64	5.57	16.53	5.36	39.55	6.24	0.9208	0.2980	0.203	0.3476
Magnesium Omitted	54.1	35.86	6.49	25.42	1.71	27.03	4.39	1.649	0.1110	1.754	0.2849
WOOD.											
Complete Nutrient	86.5	49.01	1.11	11.65	4.73	20.69	12.93	0.1293	0.0525	0.2297	0.1435
Potassium Omitted	66.5	50.31	0.73	21.01	7.82	11.48	19.45	0.1534	0.0571	0.0838	0.1417
Calcium Omitted	75.6	46.65	1.17	8.70	5.87	40.89	9.21	0.1018	0.0687	0.5785	0.1077
Magnesium Omitted	74.0	46.30	1.33	12.34	2.09	37.36	5.94	0.1642	0.0278	0.4969	0.0790
WINTER PRUNED TREES.											
BARK.											
Complete Nutrient	167.5	39.71	6.19	15.52	4.42	35.85	5.49	0.9607	0.2736	2.219	0.3398
Potassium Omitted	182.9	46.67	5.64	30.17	5.04	16.77	7.57	1.702	0.2843	0.9458	0.4270
Calcium Omitted	157.6	41.50	5.60	13.51	5.51	43.63	6.27	0.7565	0.3086	2.443	0.3512
Magnesium Omitted	54.1	37.68	6.32	27.50	1.71	25.80	5.10	1.738	0.1081	1.630	0.3223
WOOD.											
Complete Nutrient	331.3	48.84	1.13	11.56	5.33	31.12	11.58	0.1419	0.0602	0.3518	0.1308
Potassium Omitted	368.0	53.56	0.70	22.19	10.59	20.68	22.32	0.1553	0.0741	0.1448	0.1562
Calcium Omitted	304.5	50.16	1.03	9.95	6.11	41.17	12.53	0.1024	0.0629	0.4239	0.1290
Magnesium Omitted	71.9	47.09	1.25	12.94	1.67	31.47	8.81	0.1617	0.0209	0.3933	0.1101

of these on the basis of dry matter and to demonstrate points of difference between the composition of bark and wood portions.

In Tables IV a, b. and c. the data relating to CaO, MgO, K_2O and P_2O_5 in Tables I. to III. for the three omission series are presented in a convenient form to examine the effects produced by the respective "omitted" treatments on the contents of CaO etc. in the dry matter.

TABLE IV.

Showing effects of the various Deficiency Treatments on Amounts of Calcium, Magnesium, Potassium and Phosphorus in Dry Matter. The Amounts of the Elements in the Various Series are shown as percentages of the Amounts of the respective Elements in the Complete Nutrient Series for each Sampling.

a. *Summer Pruned Series.*

Material and Series.	Dates of Sampling.	CaO. %	MgO. %	K_2O. %	P_2O_5. %
LEAVES.					
Potassium Omitted	29/7/26	141.5	151.9	**34.63**	116.9
	13/6/27	148.0	78.52	**37.18**	115.9
	7/7/28	238.8	249.6	**19.62**	91.5
Calcium Omitted	29/7/26	**87.80**	96.42	104.6	113.8
	13/6/27	**86.08**	107.7	109.7	105.8
	7/7/28*	**67.14**	92.96	83.8	48.5
Magnesium Omitted	29/7/26	101.4	**48.93**	104.6	110.6
	13/6/27	103.9	**41.91**	123.4	140.9
	7/7/28	149.1	**39.22**	124.7	146.1
STEMS AND PETIOLES.					
Potassium Omitted	29/7/26	107.3	106.5	**48.97**	119.6
	13/6/27	113.2	108.0	**38.66**	86.8
	7/7/28	156.5	139.8	**29.28**	98.9
Calcium Omitted	29/7/26	**84.41**	91.87	130.9	108.1
	13/6/27	**88.08**	115.2	114.1	53.7
	7/7/28	**94.23**	112.8	105.8	100.9
Magnesium Omitted	29/7/26	141.5	**51.31**	117.0	106.4
	13/6/27	168.4	**55.46**	110.0	59.1

* Results this series on this date probably low due to error in determining "ash in dry matter." See Table Ia.

b. *Winter Pruned Series.*

Material and Series.	Dates of Sampling.	CaO. %	MgO. %	K_2O. %	P_2O_5. %
BARK.					
Potassium Omitted	9/1/28	146.3	169.9	**52.52**	146.0
	3/12/28	132.3	170.4	**38.94**	129.1
Calcium Omitted	9/1/28	**67.89**	114.3	103.9	108.3
	3/12/28	**56.70**	121.1	91.75	107.0
Magnesium Omitted	9/1/28	189.9	**40.8**	103.7	111.9
WOOD.					
Potassium Omitted	9/1/28	105.0	111.0	**34.73**	108.0
	3/12/28	125.7	105.2	**31.85**	115.8
Calcium Omitted	9/1/28	**57.01**	111.9	111.0	100.0
	3/12/28	**59.91**	100.7	84.1	99.3
Magnesium Omitted	9/1/28	142.5	**56.44**	109.9	124.5

DISCUSSION.

From the notes given above on the growth features of the trees, it will be seen that, in the complete nutrient series, certain symptoms were shown on the foliage which suggested that the culture solution used did not provide an entirely suitable growth medium for the trees and it appeared that this was probably due to the very high content of potassium in the solution. Thus the symptoms shown on the foliage of the complete nutrient series were more strongly developed in the calcium omitted series, and were extremely severe in the magnesium omitted series but never appeared in the potassium omitted series. Moreover, shoot growth in the complete nutrient series was significantly less than in the potassium omitted series, in which series it was excellent, and it seems probable that the variety of apple used prefers a diet fairly low in potassium. It is not clear why the growth in the calcium omitted series should have been rather larger than in the complete nutrient series, though it will be seen from Table IV. that, in the former series, deficiency of calcium, as judged by the analytical results, had not been so severe as the deficiencies of potassium and magnesium in their respective omitted series, and, in previous experiments with apples, the tendency for larger shoot growth and large leaf size have been noted in calcium omitted series (2, 5). It seems probable that such a condition is brought about by " low " calcium conditions within the tree as distinct from extreme calcium starvation.

c. *Main Stems.*

Material and Series.	Dates of Sampling.	CaO. %	MgO. % %	K_2O. %	P_2O_5. %
SUMMER PRUNED.					
BARK.					
Potassium Omitted	3/12/28	152.0	106.9	**14.79**	97·54
Calcium Omitted	3/12/28	**86.88**	110.7	102.9	86.00
Magnesium Omitted	3/12/28	155·5	**41.23**	81·93	70·49
WOOD.					
Potassium Omitted	3/12/28	118.7	108.7	**36.48**	98.74
Calcium Omitted	3/12/28	**78.7**	130.8	208.3	75·08
Magnesium Omitted	3/12/28	127.0	**52.94**	216.3	55·05
WINTER PRUNED.					
BARK.					
Potassium Omitted	3/12/28	177·1	104.0	**42.63**	128.6
Calcium Omitted	3/12/28	**78.7**	112.8	110.1	105.8
Magnesium Omitted	3/12/28	108.9	**39.5**	73·47	97·1
WOOD.					
Potassium Omitted	3/12/28	109.4	123·1	**41.16**	119.5
Calcium Omitted	3/12/28	**72.2**	104.5	120.5	98.7
Magnesium Omitted	3/12/28	114.0	**34.7**	111.8	84.2

Although the trees in the potassium omitted series made larger shoot growth than in the complete nutrient series, which is not in accord with our previous experience, very definite signs of potassium starvation were shown by the development of typical leaf scorch and by the method of defoliation from shoot tip to crotch.

In connection with the larger shoot growth observed, in addition to the possibility of the variety used preferring a low potassium medium, from other experiments which we have in progress, it would appear that shoot growth in cases of potassium deficient trees is greatly influenced by maintaining a relatively low temperature in the sand, which ensures a better control of moisture by providing efficient protection against direct heating by the sun during hot weather. In the present experiments, the type of cover used was more efficient in this respect than the tarpaulin covers previously fitted and, in later experiments, boxes have been provided which are still more suitable for the purpose.

The condition of the foliage in the calcium omitted series suggested that effects due to the treatment were produced to a slight extent from the latter half of the first season. In the second and third seasons, the foliage was very definitely of poorer quality than in the complete nutrient series and developed patches of dead tissue to a much greater extent than in the latter series. The difference in foliage quality was especially marked in the summer pruned series in 1927, 1928, subsequent to pruning, in 1928 the trees failing to develop fully grown healthy leaves.

The effects produced by the magnesium omitted treatment were extremely well marked from the middle of the first season and, by the end of the second season, the trees had become so greatly affected by the treatment that they were unable to make appreciable growth in the third season.

It has been pointed out in presenting the results that the symptoms produced on the leaves by magnesium omission were rather more irregular in character than have been observed on certain other varieties previously used when the type of injury resulting was assigned the name of " blotch."

It is also important to emphasise the point that the breakdown symptoms in the calcium omitted and magnesium omitted series were similar, though much more severe in the latter, as it seems possible from our experience that calcium deficiency symptoms may be easily masked in experiments of this type if care is not taken to provide sufficient magnesium in the nutrient solutions used.

The chemical data can be discussed most conveniently by treating each table separately in the first instance and then comparing points of interest in the various tables later.

Considering first the data relating to the summer prunings in Tables I a. and b., the following points should be noted.

In Table I a., where the data are presented for the leaves, it will be noted that the figures for the corresponding determinations in the three seasons show considerable variation, due no doubt to seasonal effects on growth and to the different stages of development at which the shoots were sampled in the various seasons.

In comparing the corresponding values obtained in the four series the following points emerge.

There is no significant point in connection with the results for dry matter ; ash in dry matter tends to be uniformly low in the potassium omitted series and high in the magnesium omitted series (the value for ash in dry matter in the CaO omitted series in the third season—6.88 per cent.—is possibly inaccurate but could not be checked) ; the omission of each element is reflected in its low value as percentage of ash in the series where it is omitted and the low value is sometimes accompanied by relatively high values for the other two elements considered, the values for CaO and MgO being notably high where potassium is omitted ; the value for P_2O_5 in ash is high where potassium is omitted ; the results for ash constituents as percentage of dry matter differ somewhat from those on the basis of percentage of ash, in one case, potassium omission is not accompanied by a relatively high value for MgO and in another for high P_2O_5, while in the calcium omitted series two results for MgO and K_2O and one for P_2O_5 are different, and in the magnesium omitted series the values of CaO, K_2O and P_2O_5 are always high. The differences are due to differences in the relative values for ash in dry matter for the various series in comparison with the complete nutrient series and, in this connection, the relatively low and high values in the cases of potassium omission and magnesium omission respectively should be specially noted.

Examination of the data for petioles and stems in Table I b. show that the salient features of the results are similar to those in Table I a. and further comment is unnecessary.

In Table II. it is important to note the differences and similarities of corresponding values for bark and wood.

Percentage dry matter is less in the bark but percentage ash in dry matter is much less in the wood. Considering the values for ash constituents as percentage of ash, CaO is greater and MgO and P_2O_5 less in the bark while K_2O is similar in the two materials. It is especially important to note the much higher values for the ash constituents as percentages of dry matter in the bark than in the wood, due to the much higher ash in dry matter in the former, since this difference renders imperative the consideration of bark and wood separately in investigations on the composition of trees (see also 6) and especially in cases where shoot and stem materials of different ages are being compared since the proportions of bark to wood differ greatly with age. In these experiments the ratio $\frac{\text{Bark}}{\text{Wood}}$ in the shoots discussed above varied between 1.10 to 1.30 and in the main stems discussed below it varied from 0.48 to 0.57 in the summer pruned series and from 0.41 to 0.43 in the winter pruned series. A further point of importance relating to bark and wood is mentioned below.

Other points requiring mention are as follows : Percentage dry matter is high in both bark and wood where potassium and calcium are omitted and low in the magnesium omitted series ; ash in dry matter is low where potassium and calcium omission treatments are given and high where magnesium is omitted ; the main features noted in Table I. for the ash constituents as percentage ash and as percentage dry matter are also shown here.

The results in Table III. for bark and wood in the main stems of the summer and winter pruned series show that the composition of the respective materials in the two groups are similar and show many points in common with those in Table II. for these materials in the shoots but there are certain points of difference.

The values for percentage dry matter in both bark and wood in Table III. are similar to those in Table II.; those for percentage ash in dry matter in the bark are also fairly close in the two cases, but in the various series percentage ash in the wood of the main stems is only approximately one half of the corresponding value in the wood of the shoots, again showing the importance of separating bark and wood for analytical purposes.

The relatively low values for P_2O_5 in the wood of the magnesium omitted series are marked.

From the consideration of the data in this paper relating to bark and wood, it would appear that data such as are presented by Butler, Smith and Curry (1) and by Reed and Haas (3), showing smaller percentages of ash constituents in the dry matter of older shoots and stems than in younger shoots such as terminals, exhibit such features primarily because of the larger proportion of wood in the older stems, the bark showing relatively little variation. It is probable that similar results to the above would also be found in examining the distribution of other substances actively concerned with growth processes such as nitrogen compounds, sugars, starch, etc. Such a view is supported by the data of Tufts (4).

The method of presenting the data in Table IV. relative to the amounts of CaO, MgO, K_2O and P_2O_5 in dry matter shows in a very clear way the effects of the various omissions in lowering the percentages of the respective omitted bases in the dry matter and how each omission usually leads to an increase in the contents of the other two bases concerned. The larger decreases effected in the contents of potash and magnesia in all portions of the trees in the series in which these are omitted are evident while it is seen that the decreases in lime content are not nearly so marked. In view of this last result, it seems probable that the trees are able to obtain a certain amount of calcium either from the sand or the rain water used or from both of these.

It should be noted that when potassium is omitted there is usually a large increase in the calcium content of all materials, but where calcium is omitted there is not usually a large increase in potassium shown, which is probably due to the fact previously stated that the complete nutrient solution used is relatively high in potassium.

It is also of interest to note that, in the leaves and shoot portions, the omission of any base has generally been followed by an increase in the P_2O_5 content of the dry matter—data for stems plus petioles of summer pruned trees are variable—whereas in the main stem materials the reverse has usually occurred.

CONCLUSIONS.

1. In an experiment in which apple trees, variety Stirling Castle, planted as maidens, were grown in pots in quartz sand and the differential nutrient

treatments, complete nutrient solution, potassium omitted, calcium omitted, and magnesium omitted given, the nutrient treatments produced significant effects on the growth features and chemical composition of the trees.

2. The omission of potassium resulted in increased shoot growth, leaf scorch and defoliation of shoots in the direction from tips to crotch. Calcium omission produced slightly increased shoot growth, relatively large leaves and breakdown of leaf tissue in patches, which occurred either near the midrib, along marginal areas, or in the region of the tips. Magnesium omission effected a great reduction in shoot growth after the first season and, after two seasons, the trees were unable to make appreciable shoot growth. This omission produced the most severe leaf breakdown of the three under test. The symptoms were similar to those produced by calcium omission, though much more intense, but, in addition, a slightly chlorotic condition was produced in the later stages of the experiment.

3. All three omission treatments were reflected in the composition of the ash of all parts of the trees examined—leaves and stems plus petioles of summer pruned shoots, bark and wood of winter pruned shoots and bark and wood of the main stems. Large reductions in K_2O and MgO contents were effected in all materials by the omission of these bases but the omission of CaO did not produce such large reductions.

Omission of any one of the three elements usually resulted in higher percentages of the other two in both the ash and dry matter.

Omission of K_2O or CaO generally resulted in the production of high percentage dry matter in fresh material and low percentage ash in dry matter while the reverse effects resulted from the omission of MgO.

The respective omissions possibly affected the content of P_2O_5 in dry matter in the various parts of the trees, the percentage being generally high in the leaves and shoot portions and low in the main stems.

In examining the effect of omissions of K_2O, CaO and MgO on the contents of ash constituents in trees, it is important to calculate the amounts on a basis of dry matter and not on the ash since the percentage ash in dry matter in the cases of omissions of K_2O and CaO was found to be relatively low and in the case of MgO omission to be relatively high.

4. The contents of ash constituents in the bark and wood of shoots and main stems differ widely, due to the ash content of the bark being much higher than that of the wood. The ash content is relatively uniform in the bark from the shoot and stem portions of the trees but the percentages of ash in the wood of the shoots, one year old, is approximately twice as high as in the wood of the four year old stems.

5. In view of the results obtained for bark and wood, it is essential to consider them separately in examining the composition of shoot and stem portions of trees.

SUMMARY.

1. An account is given of an experiment continued over three seasons in which apple trees, variety Stirling Castle, were grown in quartz sand contained in plant pots and given the nutrient treatments, complete nutrient, potassium omitted, calcium omitted, and magnesium omitted respectively.

2. Observations were made on the growth features resulting from the treatments and the effects of the treatments on the composition of the leaf, shoot and stem portions of the trees were determined.

3. Each treatment produced significant effects on shoot growth and foliage characters and these are described and discussed.

4. The various omissions were reflected in the composition of the dry matter of all portions of the trees examined. Large decreases in the contents of K_2O and MgO were effected by deficiencies of these but the decreases in CaO were much less.

5. The bark and wood portions of one-year shoots and four-year-old main stems showed wide differences in their contents of ash and ash constituents and it is concluded that in investigations on the composition of shoots and stems of trees, it is essential to examine the bark and wood separately.

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EXPERIMENTS ON THE EFFECTS OF LEACHING WITH COLD WATER ON THE FOLIAGE OF FRUIT TREES.

I. THE COURSE OF LEACHING OF DRY MATTER, ASH AND POTASH FROM LEAVES OF APPLE, PEAR, PLUM, BLACK CURRANT AND GOOSEBERRY.

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In a previous paper, Mann and the writer (1) described experiments on the effects of leaching with cold water on the foliage of certain varieties of apple trees and showed that relatively large percentages of dry matter, ash constituents and potash (especially this last) could be leached from the leaves of these by immersing either detached leaves or leaves attached to terminal shoots in distilled water at ordinary room temperatures for periods varying from twenty-four hours to seventy-two hours.

Evidence was also presented to show that, in an extremely wet season such as 1924, leaching of foliage apparently occurred in the field in the cases of certain varieties to serious extents, leading to the ultimate death of a considerable amount of the damaged leaves.

Since the previous communication, the investigations have been extended to the examination of the leaching of foliage of certain varieties of pears, plums, black currants and gooseberries and further data have been secured on four varieties of apples. In these experiments, the progress of the leaching of dry matter and ash has been followed in addition to the course of the leaching of potash.

The results obtained on apples are in harmony with those previously reported whilst those reported for the other classes of fruits show that the foliage of all behaves in a similar manner to that of the apple when subjected to the leaching treatment.

EXPERIMENTAL.

The whole of the experimental work was carried out during the season of 1927.

MATERIALS.

Particulars of the trees and bushes from which material was taken are given in Table I. and the details of the materials used are shown in the notes below.

TABLE I.

Particulars of Trees and Bushes Used.

Class of Fruit and Variety.	Date of Planting.	Remarks.
APPLES.		
Allington Pippin	Autumn 1919	Vigorous trees, clean cultivated and highly manured.
Stirling Castle	,, 1923	do.
Bramley's Seedling	,, 1919	do.
Edward VII.	,, 1919	do.
PEARS.		
Winter Nelis	,, 1922	do.
Williams Bon Chrétien	,, 1922	do.
Conference	,, 1922	do.
Josephine de Malines	,, 1922	do.
PLUMS.		
Victoria	,, 1918	do.
Monarch	,, 1913	Fairly vigorous trees, clean cultivated and highly manured.
Rivers Early Prolific	,, 1913	do.
Ponds Seedling	,, 1913	Vigorous trees, clean cultivated and highly manured.
BLACK CURRANTS.		
Seabrook's Black	,, 1924	do.
Baldwin (Hereford Strain)	,, 1922	Medium vigour; clean cultivated, manured wholly with artificials.
Edina	,, 1922	Vigorous; manured wholly with artificials.
Boskoop Giant	,, 1922	do.
GOOSEBERRIES.		
Leveller	,, 1924	Vigorous bushes; clean cultivated and manured with artificials.
Keepsake	,, 1924	do.
Lancashire Lad	,, 1924	do.
Yellow Sulphur	,, 1924	do.

DETAILS OF MATERIALS USED.

APPLES:

Allington Pippin: Sample taken July 6th: a portion at 3 p.m. and remainder at 6.45 p.m. Healthy leaves of mature appearance taken from current season's shoots.

Stirling Castle: Sample taken July 6th at 4.30 p.m. Leaves large and in excellent condition; a few showed slight spotting. Sample from mature leaves of current season's shoots.

Bramley's Seedling: Sample taken July 18th at 3 p.m. Leaves large and in excellent condition; mature leaves from current season's shoots.

Edward VII: Sample taken July 12th at 2 p.m. Healthy leaves of mature appearance from current season's shoots.

PEARS:

Winter Nelis: Sample taken July 6th at 4.15 p.m.; mature leaves from current season's shoots and in excellent condition.

Williams Bon Chrétien: Sample taken July 6th at 4.30 p.m. Conditions etc. as Winter Nelis.

Conference: Sample taken July 12th at 2.30 p.m. Mature leaves from current season's shoots and in good condition.

Josephine de Malines: Sample taken July 25th at 3.15 p.m. Leaves were small; condition was only medium and, in order to obtain a fairly good sample, the leaves taken varied somewhat in shape and age.

PLUMS:

Victoria: Sample taken June 28th at 11 a.m. Mature leaves from spurs near current season's terminals. Generally excellent condition but some had holes in them of "Shot-hole" type. Unable to take leaves from current season's shoots owing to aphis effects.

Monarch: Sample taken July 12th at 3 p.m. Mature leaves from current season's shoots; excellent condition but rather below normal size for the variety.

River's Early Prolific: Sample taken July 18th at 12.30 p.m. Mature leaves from terminal shoots and in excellent condition.

Pond's Seedling: Sample taken July 12th at 3.15 p.m. Mature leaves from current season's shoots and in excellent condition.

BLACK CURRANTS:

Seabrook's Black: Sample taken July 6th at 12 noon. Mature leaves on basal sections of current season's shoots and in excellent condition.

Baldwin: Sample taken July 18th at 3 p.m. Condition etc. as Seabrook.

Edina: Sample taken July 25th at 12 noon. Condition etc. as Seabrook.

Boskoop: Sample taken July 12th at 2.45 p.m. Condition etc. as Seabrook.

GOOSEBERRIES:

Leveller: Sample taken June 28th at 12.30 p.m. Mature leaves from current season's shoots, in excellent condition and very large. A little lead arsenate on under surfaces.

Keepsake: Sample taken July 6th at 12.30 p.m. Mature leaves from current season's shoots and in excellent condition. A little lead arsenate on under surfaces.

Lancashire Lad: Sample taken July 12th at 3.30 p.m. Condition etc. as Keepsake.

Yellow Sulphur: Sample taken July 18th at 12 noon. Condition etc. as Keepsake.

Note.—In all cases the leaves were taken on bright days and were always dry.

METHODS.

The methods employed were identical with those used in the previous work.

Two samples of leaves, each weighing approximately 20 grms., were taken in each case. One of these was used as a control and determinations of dry matter, ash and potash carried out on it without leaching treatment. (See Table III.) The second sample was employed in the leaching test. In all cases, the freshly gathered leaves were conveyed to the laboratory without delay in large beakers, each beaker being covered with grease-proof paper. The petioles were removed and only the laminæ used in the determinations. The leaching treatments were carried out in cylinders of 1 litre capacity, the laminæ being placed in the cylinders and distilled water added to the 1000 c.c. mark. Each cylinder was then covered with a glass cover and placed in a cool position in the laboratory for twenty-four hours, the leaves being moved slightly in the water with a copper wire on three or four occasions during the period to ensure exposure of the leaf surfaces to the liquid.

In all cases four successive leachings of twenty-four hours' duration were given.

RESULTS.

The observations recorded on the condition of the leaves whilst undergoing the leaching treatments and on the characters of the extracts are shown in Table II.

The analytical results are summarised in Tables III., IV., V., VI., and are presented in graphic form in Figures 1-15.

TABLE II.

Observations on Foliage and Extracts during Leaching.

Materials.	1st Leaching.	2nd Leaching.	3rd Leaching.	4th Leaching.
APPLES.				
Allington ..	Leaves greenish-brown in patches, notably on under side of leaf. Extract greenish.	As 1st.	Leaves appearance as 1st. Extract yellow.	Leaves practically all brown; a few green patches. Extract slightly greenish yellow.
Stirling ..	Leaves fresh green. Extract colourless.	Leaves brown in patches. Extract slightly green.	As 2nd.	Leaves much browning; very small percentage of green remains. Extract slightly brownish green.
Bramley ..	Leaves fresh green. Extract very faintly coloured.	Leaves brownish in patches. Extract green.	Leaves greenish-brown. Extract green.	Leaves brown. Extract greenish-yellow.
Edward ..	Leaves brown in patches. Extract greenish.	Leaves brownish-green. Extract yellowish-green.	Leaves as 2nd. Extract deeply coloured.	Leaves brown. Extract deep yellow.
PEARS.				
Winter Nelis ..	Leaves brown. Extract slightly green.	Leaves as 1st. Extract yellowish green.	Leaves practically brown. Extract yellowish-brown.	Leaves brown, only a few green patches. Extract slightly brownish colour.
Williams ..	Leaves fresh green. Extract colourless.	Leaves slightly brownish-green. Extract colourless.	Leaves brownish-green. Extract brownish-green.	Leaves mostly show much browning. A few remain mostly green with brown patches. Extract brownish tinge.
Conference ..	Leaves brownish-green in patches. Extract slightly green.	Leaves almost entirely brown. Extract yellow.	As 2nd.	Leaves entirely brown. Extract yellow.
Josephine de Malines ..	Leaves green. Extract brown.	Leaves greenish-brown. Extract brown.	Leaves brown. Extract less deeply coloured than 2nd.	Leaves brown. Extract almost colourless.
PLUMS.				
Victoria ..	Leaves fresh green. Extract clear and colourless.	As 1st.	As 1st.	Leaves spotted with brown. Extract colourless.
Monarch ..	Leaves fresh green. Extract colourless.	Leaves slightly brownish-green. Extract green.	Leaves almost entirely brown. Extract green.	Leaves brown. Extract only slightly coloured.
Rivers Early Prolific ..	Leaves fresh green. Extract very slightly green.	As 1st.	Leaves show brown patches. Extract as 1st.	Leaves brown with few green patches. Extract slightly greenish-yellow.
Ponds Seedling	Leaves green. Extract slightly green.	Leaves show brown patches. Extract green.	Leaves as 2nd. Extract less colour than 2nd.	Leaves brownish-green. Extract slightly green tint.

TABLE II—*continued.*

Materials.	1st Leaching.	2nd Leaching.	3rd Leaching.	4th Leaching.
BLACK CURRANTS.				
Seabrook ..	Leaves green. Extract colourless and clear.	As 1st.	As 1st.	As 1st.
Baldwin ..	Leaves green. Extract colourless.	Leaves green. Extract colourless. May have a faint bluish tint.	As 2nd.	Leaves green. Extract colourless but slightly cloudy.
Edina ..	Leaves green. Extract colourless.	As 1st.	Leaves some brown patches. Extract as 1st but slight bluish tint.	Leaves as 3rd. Extract colourless.
Boskoop ..	Leaves green. Extract colourless.	Leaves green. Extract cloudy and very slightly green.	As 2nd.	Leaves slightly brown in patches. Extract slightly green.
GOOSEBERRIES.				
Leveller ..	Leaves green. Extract slightly green.	Leaves brownish-green. Extract green.	Leaves brown. Extract almost colourless; cloudy on standing.	As 3rd.
Keepsake ..	Leaves slightly brown. Extract slightly green.	Leaves brownish-green. Extract green.	As 2nd.	Leaves brownish-green. Extract clear and colourless.
Lancashire Lad	Leaves brownish-green. Extract green.	As 1st.	Leaves brown. Extract slightly green.	Leaves brown. Extract colourless.
Yellow Sulphur	Leaves slightly brownish-green. Extract slightly green.	As 1st.	Leaves brownish-green. Extract less coloured than 2nd.	Leaves brownish-green. Extract colourless and clear.

TABLE III.

Comparing the amounts of Dry Matter, Ash and Potash in the Leached Leaves and the Control Leaves.

Class of Fruit and Variety.	Leached Leaves.				Control Leaves.			
	Fresh wts. taken (grms).	Dry matter in fresh wt. %	Ash in Dry Matter. %	K_2O in Ash. %	Fresh wts. taken (grms).	Dry matter in fresh wt. %	Ash in Dry Matter. %	K_2O in Ash. %
APPLES.								
Allington	21.39	36.15	6.857	19.57	23.39	39.63	6.536	20.59
Stirling	23.13	36.19	7.183	18.08	21.68	37.69	7.281	19.15
Bramley	24.36	35.18	7.109	26.84	20.13	37.72	6.940	26.27
Edward VII.	23.42	33.92	8.557	21.77	20.31	35.39	7.902	24.12
PEARS.								
Winter Nelis	24.40	31.60	—	—	23.73	36.56	6.779	24.80
Williams Bon Chrétien	22.18	41.10	7.832	15.92	21.16	44.42	7.300	16.00
Conference	21.31	35.56*	9.537	11.99	21.07	39.65	8.226	13.45
Josephine	27.08	36.52	8.072	17.99	19.79	37.84	7.330	19.69
PLUMS.								
Victoria	22.57	—	—	28.61	22.88	34.01	11.18	29.46
Monarch	21.06	31.13†	10.17	—	21.49	33.39	8.876	29.71
Rivers Early Prolific	22.26	31.85	10.09	34.49	22.01	35.52	9.428	36.00
Ponds Seedling	23.83	34.59*	7.357	20.31	22.70	37.55	6.454	21.32
BLACK CURRANTS.								
Seabrook	21.52	29.27	14.82	13.15	23.41	32.15	12.09	14.38
Baldwin	23.28	30.27	11.82	14.72	23.05	35.24	10.55	13.90
Edina	26.58	29.18†	11.84	11.69	21.01	33.22	9.69	13.10
Boskoop	22.88	31.29*	13.14	9.40	22.14	35.10	12.12	9.53
GOOSEBERRIES.								
Leveller	22.50	26.32	14.18	30.73	20.11	27.36	14.64	31.82
Keepsake	23.80	25.08	15.35	28.33	23.95	26.11	15.63	29.24
Lancashire Lad	22.90	29.20†	12.68	24.44	18.32	30.25	12.05	27.83
Yellow Sulphur	20.08	28.16	11.57	28.47	20.65	30.02	11.45	28.72

* Denotes one of fractions composing this badly charred. † Denotes one of fractions composing this slightly charred.

TABLE IV.

Showing the Course of the Leaching of Dry Matter during Consecutive Periods of twenty-four hours.

Class of Fruit and Variety	Actual Weights of Dry Matter in Leachings and Residues. (grms.)							Dry Matter in Leachings and Residues as percentages of Total Dry Matter Recovered.						
	1st 24 hrs.	2nd 24 hrs.	3rd. 24 hrs.	4th 24 hrs.	Residue	Total Leached.	Total Recovered.	1st. 24 hrs.	2nd. 24 hrs.	3rd. 24 hrs.	4th. 24 hrs.	Residue.	Total Leached.	Totals.
APPLES.														
Allington	0.2794	1.1233	0.6944	0.2520	5.3830	2.3491	7.7321	3.61	14.52	8.98	3.26	69.61	30.37	99.98
Stirling	0.2642	1.0545	0.9047	0.1925	5.9550	2.4159	8.3709	3.16	12.60	10.81	2.30	71.14	28.87	100.01
Bramley	0.4452	1.0132	0.5208	0.2100	6.3790	2.1892	8.5682	5.20	11.82	6.08	2.45	74.44	25.55	99.99
Edward VII. ..	1.1333	0.8924	0.1500	0.0248	5.7440	2.2005	7.9445	14.26	11.23	1.89	0.31	72.30	27.69	99.99
PEARS.														
Winter Nelis	0.5644	0.5892	0.6452	0.2041	5.7075	2.0029	7.7104	7.32	7.64	8.37	2.65	74.03	25.98	100.01
Williams Bon Chrétien	0.2054	0.6137	0.9876	0.4667	6.8420	2.2734	9.1154	2.25	6.74	10.83	5.12	75.08	24.94	100.02
Conference	1.0985	0.5550*	0.2608	0.0940	5.4710	2.0083	7.4793	14.70	7.42	3.49	1.26	73.16	26.87	100.03
Josephine de Malines	1.9970	1.2764	0.2358	0.0720	6.3070	3.5812	9.8882	20.19	12.90	2.38	0.73	63.77	36.20	99.97
PLUMS.														
Victoria	0.0708	0.0444	0.0336	0.0896	—	—	—	—	—	—	—	—	—	—
Monarch	0.2830	0.9970	0.6460	0.1270†	4.5030	2.0530	6.5560	4.32	15.21	9.85	1.94	68.69	31.32	100.01
Rivers Early Prolific ..	0.0918	0.1730	0.5306	0.6370	5.6620	1.4324	7.0944	1.29	2.44	7.48	8.98	79.84	20.19	100.03
Ponds Seedling ..	0.5827*	0.9054	0.7186	0.2400	5.7990	2.4467	8.2457	7.07	10.98	8.72	2.91	70.34	29.68	100.02
BLACK CURRANTS.														
Seabrook	0.0764	0.0362	0.1061	0.2003	5.8760	0.3190	6.2950	1.21	0.58	1.68	3.18	93.33	6.65	99.98
Baldwin	0.1250	0.0960	0.0918	0.0984	6.6350	0.4112	7.0462	1.77	1.36	1.30	1.40	94.14	5.85	99.97
Edina	0.3530†	0.2690	0.2028	0.1460	6.7870	0.9708	7.7578	4.55	3.47	2.61	1.88	87.50	12.51	100.01
Boskoop	0.3918	0.4634	0.2780	0.1874*	5.8370	1.3206	7.1576	5.47	6.47	3.88	2.62	81.55	18.44	99.99
GOOSEBERRIES.														
Leveller	0.3112	0.9290	0.2706	0.0836	4.3300	1.5944	5.9244	5.25	15.68	4.57	1.41	73.10	26.91	100.01
Keepsake	0.7202	0.6914	0.1378	0.0670	4.3540	1.6164	5.9704	12.06	11.58	2.31	1.12	72.93	27.07	100.00
Lancashire Lad ..	1.4808	0.4300	0.0794†	0.0294	4.6680	2.0196	6.6876	22.15	6.43	1.19	0.44	69.79	30.21	100.00
Yellow Surphur ..	0.7608	0.5754	0.0948	0.0343	4.1900	1.4653	5.6553	13.46	10.17	1.68	0.61	74.09	25.92	100.01

* Badly charred. † Some charring.

TABLE V.

Showing the Course of the Leaching of Ash during Consecutive Periods of twenty-four hours.

Class of Fruit and Variety.	Actual Weights of Ash in Leachings and Residues. (grms.).							Ash in Leachings and Residues as percentages of Total Ash Recovered.						
	1st 24 hrs.	2nd. 24 hrs.	3rd. 24 hrs.	4th. 24 hrs.	Residue.	Total Leach-ed.	Total Recov-ered.	1st. 24 hrs.	2nd. 24 hrs.	3rd. 24 hrs.	4th. 24 hrs.	Residue.	Total Leached.	Totals.
APPLES.														
Allington	0.0568	0.1228	0.0918	0.0357	0.2230	0.3071	0.5301	10.71	23.16	17.31	6.73	42.24	57.91	100.15
Stirling	0.0484	0.1124	0.1195	0.0280	0.2930	0.3083	0.6013	8.05	18.70	19.90	4.66	48.70	51.31	100.01
Bramley	0.0936	0.1434	0.0800	0.0501	0.2420	0.3671	0.6091	15.37	23.55	13.17	8.22	39.70	60.31	100.01
Edward	0.2145	0.1514	0.0336	0.0092	0.2710	0.4087	0.6797	31.55	22.26	4.94	1.35	39.53	60.10	99.63
PEARS.														
Winter Nelis	0.0812	—	0.0714	0.0348	0.3010	—	—	—	—	—	—	—	—	—
Williams Bon Chrétien	0.0465	0.0742	0.0770	0.0552	0.4610	0.2529	0.7139	6.51	10.40	10.80	7.73	64.60	35.44	100.04
Conference	0.1355	0.1230	0.0430	0.0204	0.4010	0.3219	0.7229	18.48	17.02	5.95	2.82	55.48	44.27	99.75
Josephine de Malines..	0.2238	0.1344	0.0320	0.0152	0.3930	0.4054	0.7984	28.03	16.84	4.01	1.90	49.22	50.78	100.00
PLUMS.														
Victoria	0.0334	0.0118	0.0168	0.0296	0.7430	0.0916	0.8346	4.00	1.41	2.01	3.55	89.03	10.97	100.00
Monarch	0.0634	0.1484	0.0980	0.0354	0.3220	0.3452	0.6672	9.50	22.24	14.70	5.30	48.30	51.74	100.04
Rivers Early Prolific	0.0348	0.0384	0.0924	0.0978	0.4520	0.2634	0.7154	4.86	5.37	12.93	13.66	63.20	36.82	100.02
Ponds Seedling ..	0.1035	1.1018	0.0550	0.0252	0.3210	0.2855	0.6065	17.06	16.80	9.07	4.12	52.90	47.05	99.95
BLACK CURRANTS.														
Seabrook	0.0278	0.0136	0.0486	0.0915	0.7520	0.1815	0.9335	2.98	1.46	5.45	9.81	80.60	19.70	100.30
Baldwin	0.0430	0.0384	0.0318	0.0390	0.6810	0.1522	0.8332	5.16	4.61	3.82	4.68	81.74	18.27	100.01
Edina	0.1470	0.0696	0.0583	0.0553	0.5880	0.3302	0.9182	16.01	7.56	6.35	6.02	64.04	35.94	99.98
Boskoop	0.1140	0.1352	0.0990	0.0634	0.5290	0.4116	0.9406	12.12	14.37	10.52	6.74	56.24	43.75	99.99
GOOSEBERRIES.														
Leveller	0.0980	0.2400	0.0768	0.0420	0.3830	0.4568	0.8398	11.67	28.58	9.15	5.00	45.60	54.40	100.00
Keepsake	0.1908	0.2082	0.0654	0.0298	0.4220	0.4942	0.9162	20.83	22.73	7.14	3.25	46.06	53.95	100.01
Lancashire Lad ..	0.2904	0.1100	0.0296	0.0148	0.4030	0.4448	0.8478	34.26	12.97	3.49	1.75	47.53	52.47	100.00
Yellow Sulphur ..	0.1688	0.1346	0.0258	0.0093	0.3160	0.3385	0.6545	25.80	20.55	3.94	1.42	48.26	51.71	99.97

TABLE VI.

Showing the Course of the Leaching of K_2O during Consecutive Periods of twenty-four hours.

Class of Fruit and Variety.	Actual Weights of Potash (K_2O) in Leachings and Residues (grms.).							Potash (K_2O) in Leachings as percentages of Total Recovered.						
	1st 24 hrs.	2nd. 24 hrs.	3rd. 24 hrs.	4th. 24 hrs.	Residue.	Total Leached.	Total Recovered.	1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.	4th 24 hrs.	Residue.	Total Leached.	Totals.
APPLES.														
Allington Pippin	0.0239	0.0402	0.0303	0.0684	0.0010	0.1028	0.1038	23.03	38.73	29.19	8.10	0.96	99.05	100.01
Stirling Castle	0.0180	0.0465	0.0390	0.0034	0.0018	0.1069	0.1087	15.12	42.78	35.96	3.13	2.81	96.99	99.80
Bramley's Seedling	0.0443	0.0639	0.0330	0.0135	0.0088	0.1547	0.1635	27.09	39.08	20.19	8.25	5.38	94.16	99.99
Edward VII.	0.0880	0.0496	0.0075	0.0029	0.0001	0.1479	0.1480	59.46	33.51	5.07	1.96	0.09	100.00	100.00
PEARS.														
Winter Nelis	0.0367	—	0.0249	0.0096	0.0066	—	—	—	—	—	—	—	—	—
Williams Bon Chrétien	0.0247	0.0310	0.0261	0.0125	0.0187	0.0949	0.1136	21.74	27.38	22.98	11.00	16.46	83.10	99.56
Conference	0.0484	0.0270	0.0052	0.0015	0.0046	0.0821	0.0867	55.83	31.13	6.00	1.73	5.31	94.69	100.00
Josephine de Malines	0.0885	0.0394	0.0063	0.0058	0.0046	0.1390	0.1436	61.63	27.43	4.38	4.04	3.20	97.48	100.68
PLUMS.														
Victoria	0.0107	0.0074	0.0134	0.0146	0.1926	0.0461	0.2387	4.48	3.10	5.61	6.12	80.68	19.31	99.99
Monarch	0.0316	—	0.0400	0.0131	0.0121	—	—	—	—	—	—	—	—	—
Rivers Early Prolific	0.0165	0.0181	0.0507	0.0517	0.1098	0.1370	0.2468	6.68	7.28	20.07	20.94	44.48	54.97	99.45
Ponds Seedling	0.0248	0.0468	0.0356	0.0048	0.0040	0.1120	0.1160	21.38	40.34	30.69	4.14	3.45	96.55	100.00
BLACK CURRANTS.														
Seabrook	0.0088	0.0058	0.0103	0.0141	0.0840	0.0390	0.1230	7.15	4.72	8.37	11.46	68.27	31.70	99.97
Baldwin	0.0168	0.0140	0.0115	0.0121	0.0628	0.0544	0.1226	13.70	11.43	9.38	9.85	55.63	44.35	99.98
Edina	0.0284	0.0149	0.0108	0.0082	0.0450	0.0623	0.1073	26.47	13.89	10.07	7.64	41.94	58.07	100.01
Boskoop	0.0077	0.0190	0.0162	0.0116	0.0339	0.0445	0.0884	8.71	21.50	18.32	13.43	38.35	61.95	100.30
GOOSEBERRIES.														
Leveller	0.0462	0.1230	0.0502	0.0202	0.0185	0.2396	0.2581	17.90	47.65	19.45	7.83	7.16	92.83	99.99
Keepsake	0.0913	0.1044	0.0496	0.0107	0.0036	0.2560	0.2596	35.17	40.22	19.11	4.12	1.39	98.62	100.01
Lancashire Lad	0.1328	0.0545	0.0101	0.0051	0.0013	0.2025	0.2038	65.17	26.74	4.95	2.50	0.64	99.36	100.00
Yellow Sulphur	0.0927	0.0729	0.0117	0.0044	0.0047	0.1817	0.1864	49.73	39.11	6.27	2.36	2.43	97.47	99.90

Discussion.

In selecting the various samples for these investigations, a preliminary list of varieties for each class of fruit was prepared which it was thought included some likely to leach easily and others likely to prove more resistant to the treatment. It was also proposed that, in the case of each class of fruit, the material of the varieties employed should be taken from trees or bushes of fairly comparable age.

As it was necessary to obtain the material in the Research Station plantations, it was found impossible to adhere to the initial proposals. Thus, in the case of apples, suitable trees of Cox's Orange Pippin, a variety very readily leached, were not available and the trees of Stirling Castle employed were younger than the other three varieties used ; of plums, it was proposed to include the hardy variety Pershore Egg and the less hardy variety Purple Pershore, and Victoria could not be obtained of comparable age to the other three varieties used ; of the black currants available, Seabrook's Black was younger than the other three varieties ; among the gooseberries, a suitable sample of Whinham's Industry could not be obtained. It will be seen from Table I. that, apart from the exceptions mentioned above, the ages of the varieties in each class of fruit were identical. The notes on the samples employed also show that in all cases the leaves were of healthy appearance and seemed to be in excellent condition with the exception of Josephine de Malines, which variety produces foliage of poor quality in the Station plantations and which was selected as being likely to leach readily.

The observations recorded in Table II. show that, with the exceptions of the black currant varieties and the Victoria plum, the leaching treatments produced considerable effects on the leaves, the green colour often being entirely destroyed—sometimes as the result of a single leaching treatment—whilst the extracts at some stage of the leachings were coloured, the colours varying from green to brown.

These observations indicated the resistant nature of the black currant leaves and those of the Victoria plum, and these observations are confirmed by the analytical results.

The data presented for the leached leaves and control leaves in Table III. indicate the degree of recovery effected in the determinations of dry matter, ash and potash from the leachings and residues in each case. The data for the leached leaves are calculated from the sums of the amounts recovered in the four leachings and the residues.

These results show that the recovery by the leaching method was, in general, highly satisfactory, though in some cases there are appreciable losses in dry weight. These losses are due to small portions of the leaves breaking off during immersion and being subsequently lost on the filter and to some colloidal material being poured on to the filter and being retained in the pores. In a few cases losses were also due to charring of the leachings during the drying operations.

These losses in dry matter are reflected in the higher values for ash in dry matter in the leached leaves than in the control leaves. The percentages of potash in the ash are usually slightly lower in the leached than in the control series due to the relatively small quantities of potash to be estimated in some of the leachings.

There are certain points in these results which call for comment, viz.:

1. The percentages of dry matter in the gooseberry leaves are appreciably lower than in the cases of the other fruits.
2. Ash in dry matter in the gooseberry varieties is definitely high in comparison with the other classes of fruits; it is relatively high in the black currant varieties; it shows a wide range in the plum varieties, Victoria being high and Pond's Seedling extremely low; and it is relatively low in the apple and pear varieties.
3. The potash content in the ash of the black currant varieties is outstandingly low and is especially so in Boskoop; in the pear varieties, it is variable and inclined to be low; of the plums it is relatively low in Ponds Seedling.

The results summarised in Tables IV, V, VI and represented graphically in Figures 1-15, show the course of the leaching of dry matter, ash and potash in the various cases.

The salient points which emerge from these data are as follows:

The percentages of dry matter leached from the apple varieties range from 25.55% to 30.37%; from the pears the range is from 24.94% to 36.20%—Josephine de Malines showing a high value; values for plums are only available for three varieties, the range being from 20.19% to 31.32%, River's Early Prolific yielding a low percentage, whilst it is also clear that Victoria would have given a much lower value than Rivers; the black currant varieties all yield low percentages in comparison with the other classes of fruits—especially Seabrook's and Baldwin—the range being from 5.85% to 18.44%; the range for the gooseberry varieties is very similar to that of the apple varieties, being from 25.92% to 30.21%.

The percentages of ash which are leached are always considerably higher than the percentages of dry matter removed, showing that a larger proportion of ash than of dry matter is readily soluble in cold water. The ratios $\frac{\%\ \text{ash}}{\%\ \text{dry matter}}$ leached are not similar for all the classes of fruits. Thus in the cases of the apple and gooseberry varieties, this ratio is approximately 2.0, but in the case of the black currant varieties, it is approximately 3.0, for the pears approximately 1.5 and for the plums 1.7.

Here again the results show notable features both for the different classes of fruits and for certain varieties. The percentages leached from the apple varieties range from 51.31% to 60.31%, with Stirling showing a low value ; the pear varieties show a large range, 35.44% to 50.78%, Williams being relatively low and Josephine high ; in the plum varieties, the result for Victoria is notable, being only 10.97%, and the value for Rivers is also low ; the values for the black currant varieties are again low, ranging from 18.27% to 43.75% and show the two well-marked groups ; the gooseberry varieties show a very narrow range, from 51.71% to 54.40%.

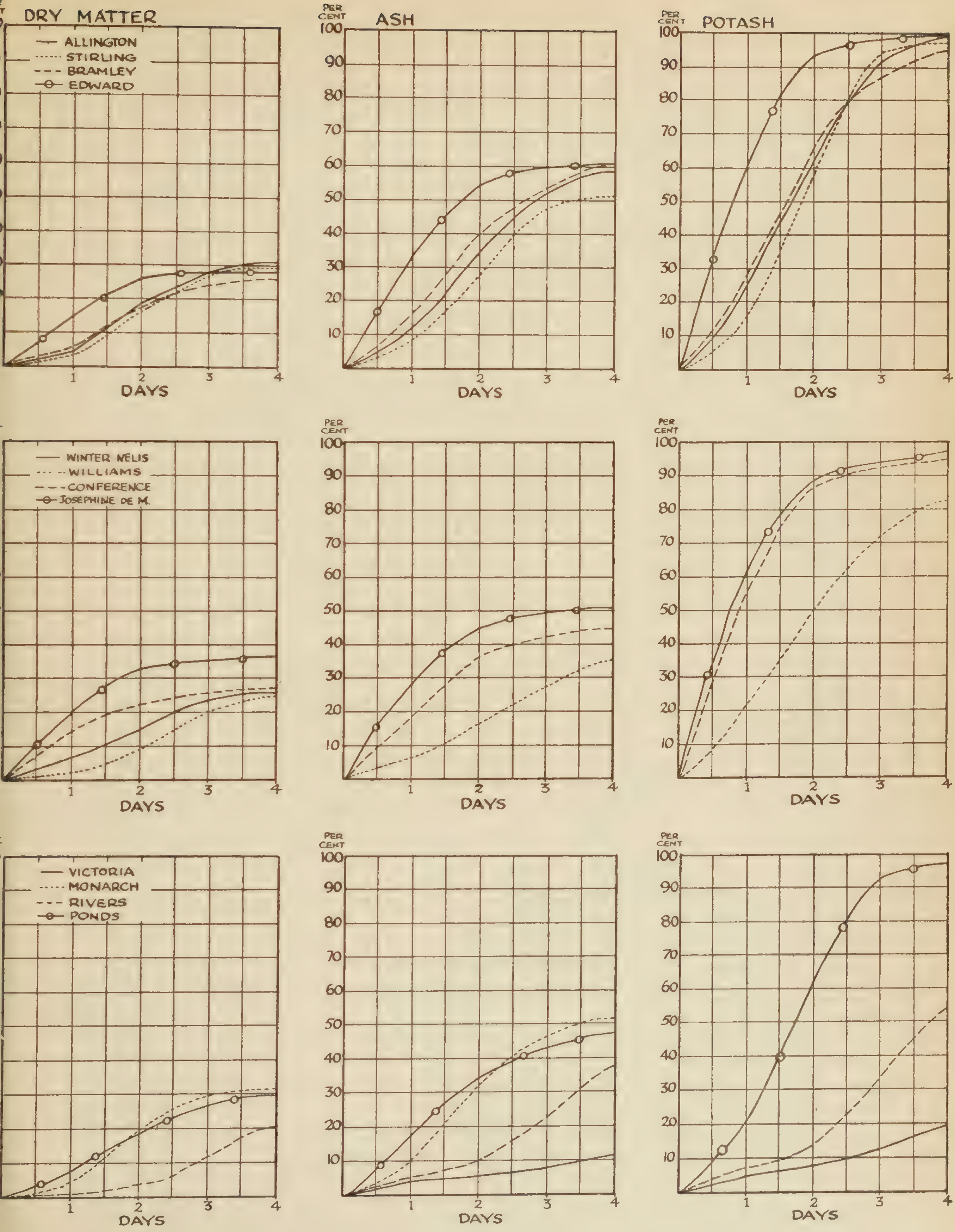
The percentages of potash leached are considerably higher than the percentages of ash removed. In the cases of the apple and gooseberry varieties, practically the whole of the potash was obtained in the leachings. Of the three pears for which values were obtained, Josephine and Conference had lost nearly the whole of their potash by leaching whilst Williams had also lost over 80% ; the values obtained for the plums show an enormous range, the resistant Victoria had only lost 19.31%, whilst 96.55% had been removed from Pond's Seedling ; the black currant varieties show a wide range and the two groups are again obvious. The ratios $\frac{\%\ \text{potash}}{\%\ \text{ash}}$ leached show variations both for classes of fruits and varieties.

The smooth nature of the summation curves showing the course of leaching of dry matter, ash and potash show that the process of leaching for each of these is continuous while the similarity in shape for each of these in any variety indicates that, in all probability, the same groups of materials are being leached at all times during the period of leaching. The most common form of curve is the sigmoid indicating that leaching proceeds most rapidly during the middle periods and falls off during the final stages when the supplies of readily leachable material become comparatively scarce.

The ratios of the percentages of $\frac{\text{potash}}{\text{ash}}$ and $\frac{\text{ash}}{\text{dry matter}}$ leached and the similarities and differences to the behaviour of the various classes of fruits and the different varieties are also clearly shown by the curves.

CONCLUSIONS.

1. Healthy leaves of varieties of apples, pears, plums, black currants and gooseberries, when subjected to leaching by immersing the laminæ in distilled water contained in glass cylinders of 1 litre capacity and retained in this way at laboratory temperatures for four successive periods of twenty-four hours, lost considerable proportions of potash, ash and dry matter by leaching.


DRY MATTER
ALLINGTON
STIRLING
BRAMLEY
EDWARD
PER CENT
ASH
POTASH
100
90
80
70
60
50
40
30
20
10
1
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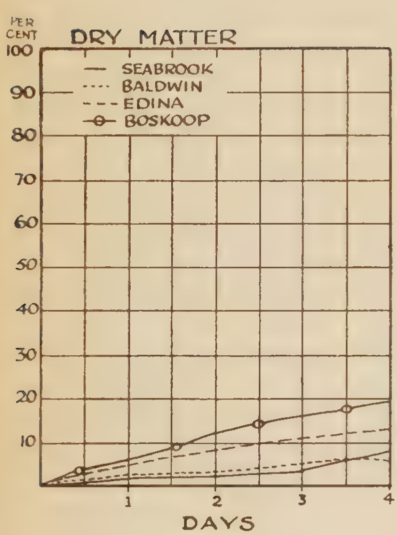
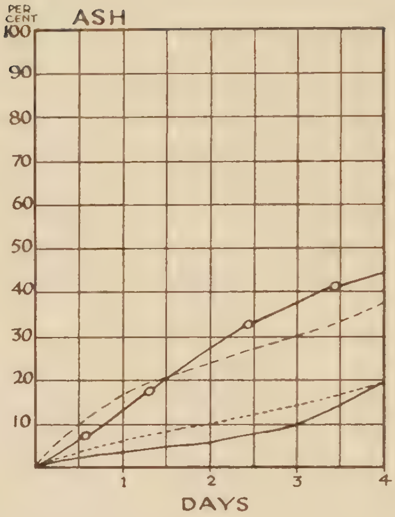
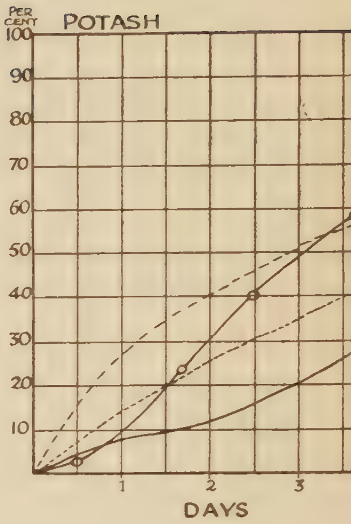
DAYS
WINTER NELIS
WILLIAMS
CONFERENCE
JOSEPHINE DE M.
VICTORIA
MONARCH
RIVERS
PONDS



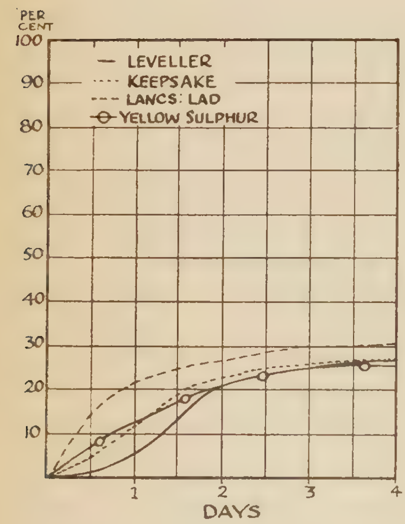
DRY MATTER

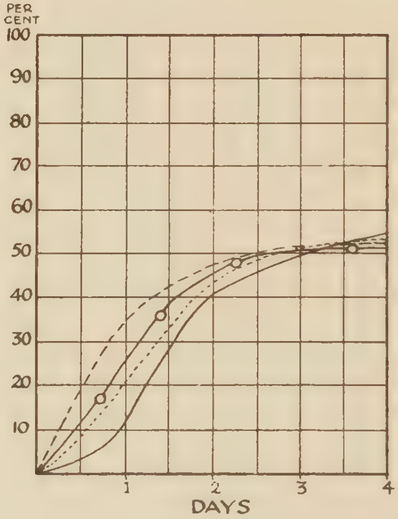


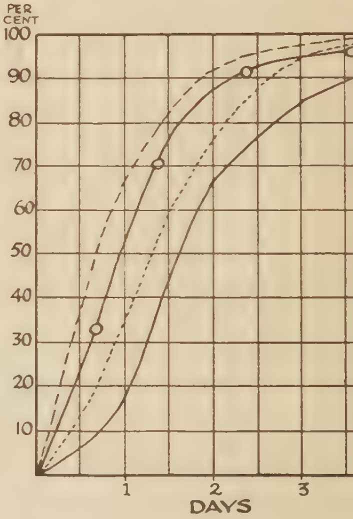
ASH



POTASH







2. The proportion of potash leached was greater than the proportion of ash and the proportion of ash greater than the proportion of dry matter.

3. The ratios of $\frac{\%\ \text{potash}}{\%\ \text{ash}}$ and $\frac{\%\ \text{ash}}{\%\ \text{dry matter}}$ leached varied for the different classes of fruits and for the different varieties.

4. All varieties of apples and gooseberries were readily leached; pears were also fairly readily leached; the plum varieties showed much variation, Victoria being extremely resistant to leaching; as a class, black currants were the least readily leached, and especially the varieties Seabrook's Black and the Herefordshire Baldwin.

5. Summation curves show that the leaching processes were continuous and the shapes of the curves for potash, ash and dry matter in the case of each variety suggest that the same groups of materials were leached throughout the leaching periods.

SUMMARY.

1. Healthy leaves of well-known varieties of apples, pears, plums, black currants and gooseberries were subjected to leaching treatment for four successive periods of twenty-four hours by immersing in distilled water contained in glass cylinders of one litre capacity, the cylinders being kept in a cool laboratory during the treatments.

2. The leaching produced visible effects on the leaves which frequently showed brown spotting or became entirely brown. The extracts also were frequently coloured green or brown.

3. The course of leaching of dry matter, ash and potash was followed by pouring off the leaching water at intervals of twenty-four hours and analysing the filtered extracts.

4. Determinations on control series of unleached leaves showed that the methods used in recovering dry matter, ash and potash in the leaching experiments were satisfactory.

5. The results obtained show that considerable proportions of dry matter, ash and potash—especially the latter, where the amount may be approximately 100%—can be leached from all the varieties tested.

6. The different classes of fruits and the various varieties showed different degrees of resistance to the treatment. Black currants proved to be the most resistant class, but the plum Victoria was more resistant than any of the black currant varieties.

7. Summation curves showing the course of leaching show that the process is continuous, the common form of curve being the sigmoid, and the similarity

of the shapes for potash, ash and dry matter for each variety suggest that the same groups of materials are being leached throughout the periods of the treatments.

ACKNOWLEDGMENT.

The analytical determinations entailed in these investigations were carried out by Mr. A. N. Dunsby, B.Sc., to whom best thanks are accorded.

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THE TIME OF DIFFERENTIATION OF THE FLOWER-BUD OF THE APPLE.

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INTRODUCTION.

It is now common knowledge that the flowers of most fruit trees are formed during the summer preceding the spring in which they open. The exact time of this differentiation, the sequence and the order of floral development have been the subject of considerable study and investigation during recent years, particularly in America. E. S. Goff (5) as early as 1899 investigated the flower bud formation of the apple, plum, pear and some small fruits such as the currant and gooseberry. He recorded a common order of flower part formation, namely, sepals, petals, stamens and finally the carpels. After the flower bud initiation, development was continued slowly until leaf fall and early winter. Then followed a period of retarded development which continued throughout winter. This was in its turn followed by a vigorous development in spring starting about March and ending in the full development of complete flowers in May.

The plum has been investigated from this standpoint by Goff (5) and Drinkard (4) in America, Luytens (6) in Holland, and Ball (1) at Long Ashton, England. These workers find that the time of differentiation varies according to the species under investigation, but that in general the flower bud initiation takes place from mid-July to early August. Ball (1) has shown, further, that climatic conditions influence the time of the differentiation. For the cherry in America, Drinkard (4) and Goff (5) found the first flower primordia in the first two weeks of July. Luytens and De Vries (7) working on the pear in Holland, found that differentiation began in early August.

Bradford (2) using the Yellow Newton variety of apple and working in the Pacific Northwest found that the flower primordia appeared during the first ten days of July. Tufts and Morrow (11) give June 11th as the earliest date on which they were able to observe it. Goff (5) in his work on the apple found two periods of differentiation, one in July and another in September, and Magness (8) has shown that the axillary buds do not show flower bud primordia until at least a month later than do spur buds. Bijhouer (3) in Holland found that flower parts were initiated about the middle of June.

Ranker (9) working on the "Delicious" apple in U.S.A., found that differentiation began in a few buds by June 19th and was general by July 2nd, and complete by August 17th. There was no second period of differentiation. All the trees from one orchard were a week behind in all the stages of flower bud formation, and this was correlated with a heavier type of soil.

It is clear, therefore, that in this matter of the time of flower-bud initiation, there is considerable variation. Climatic conditions, age of tree, rootstock, variety, cultural conditions and pruning treatment may all exert an influence. The time of flower-bud initiation is obviously a critical period in orchard management, because there can be no crop unless there is adequate blossoming. In order, therefore, to obtain the best results it is necessary to have a reasonable idea of this time *for the locality under consideration.* It is, therefore, a matter that should be worked out in every large fruit growing area. Workers in other countries may give us approximate times, but the present authors would argue for the desirability of this to be worked out under known conditions for each area. Clearly in our own country in most years there will no doubt be several weeks' difference between the time of flower bud initiation in the East and in the West of England. Further, the fruiting habit of the trees must be considered for some varieties are known to bear the major part of their crop on the tips and at axillary buds on one year old wood. Since various phases of "The Factors Governing Fruit Bud Formation" have been under investigation at Long Ashton for many years now, the present study was started in order to fix this time for our own area. Trees of the variety Lane's Prince Albert were used because they were in that condition where they were bearing on spurs and on current year's wood, so that it was possible to study the time of flower bud formation at these two tree "positions" on the same trees.

EXPERIMENTAL METHOD AND MATERIAL.

The variety of apple Lane's Prince Albert of about ten years old growing upon Malling Type 2 rootstock was used in this investigation. The trees were growing under clean cultivation and were still making fairly good growth. They carried a heavy crop in 1927 but only a light crop in 1928, the year when the examination was made. Buds were collected from three similar trees so that there can be no question of disturbed growth owing to the removal of buds and leaf surface.

Three series or classes of buds were collected, five buds at each picking at weekly intervals from early June to late August and then fortnightly until November. The first series was that of spur buds from single spurs growing on three year old, i.e., 1926, wood. The second series was that of spur buds from single spurs on two year old, i.e., 1927, wood. The third series was of axillary buds on the current season's wood, i.e., 1928, shoot growth. The collection of the first series was begun in June, the second series in July and the third series in August.

All buds were removed close to the base with a sharp knife and placed immediately into Gilson's fixative fluid, and were then removed to the laboratory where they were evacuated in the fixative from twenty-four to forty-eight hours. They were then washed and dehydrated through the alcohols following the usual technique. When the buds were in 70% alcohol they were cut off from the woody base and the outer scale leaves were removed. The buds were then passed on into absolute alcohol, cleared in xylol and embedded in wax, of a melting point 50°C.

When the first block was cut no sections were obtained, the material falling to pieces. This was found due to a layer of air caught in the hairs between each set of bud scales. Various methods were tried to free the bud from air and the following was ultimately found to be satisfactory. The buds were taken back through xylol and the alcohols to water. The tips were removed and the scales dissected off to the growing point. The buds were then evacuated in air-free distilled water, and passed up through the alcohols with evacuation in each. They were cleared in chloroform, embedded in vacuo at both the paraffin stages. The sections were stained with hæmatoxylin.

The criterion of the beginning of a flower bud initation is that given by the workers cited earlier, namely a preliminary flattening of the apex of the growing point (see Figs. 1 and 2). This appears to be the first morphological evidence of the impending subsequent development. Clearly, as indicated by Swarbrick (10) the determinative influence must be operative even earlier than the observed flattening of the apex of the growing point. At the present stage of our knowledge, however, we must be content with this first morphological evidence, but in determining practice we should bear in mind this probability and act accordingly.

RESULTS.

First Series, i.e. Spur buds from single spurs on 1926 wood.

Buds of this series collected during the first two weeks of June showed only a purely vegetative structure (see Fig. 1). Sections from a bud of this series gathered on June 25th showed the preliminary stages of flower bud formation, namely the flattening and broadening of the growing point apex (see Fig. 2). Several buds of the next picking—July 2nd—showed distinct flower bud primordia in the form of small projections one on each side of the apex (see Fig. 3). These primordia continued to develop and be initiated throughout July, so that by the 18th of August the sepal primordia were well developed although at this date the petal primordia were not yet initiated (see Fig. 6).

Second Series, i.e. Spur buds from spurs on 1927 wood.

The first buds examined from the first gathering of this series on July 2nd were found to have distinct flower bud primordia at about the same stage of development as the buds of series one gathered on the same day (see Fig. 4). Subsequent pickings in this series showed the same stages of flower bud initiation and development was proceeding at about the same rate as in the buds of series one (see Fig. 5). The sepal primordia of this series were first seen in buds gathered on July 22nd.

Third Series, i.e. axillary buds on 1928 shoot growth.

As mentioned earlier the collection of these buds was not begun until the first week in August. At this time flower primordia were present in some of the buds gathered. By the 18th August the sepal primordia were initiated and development was proceeding rapidly.

SUMMARY AND CONCLUSIONS.

A study of the time of flower bud differentiation in the spur and axillary buds of apple trees has been carried out at Long Ashton in the summer of 1928. In the buds of spurs on one and two year old wood it was found that the differentiation of the flower parts begins to take place at about the same time, that is during the last fortnight in June. Sepal primordia were distinguishable in these buds on July 2nd, 1928. On the current year's wood not all the axillary buds developed into flower buds. In those cases where blossoms were initiated the primordia were found present in buds of the first gathering which was made on the 4th August, 1928, but at this time the primordia were in the same stage of development as the spur buds were on July 2nd, that is over a month earlier. Thus, flower bud differentiation when it occurred in axillary buds on current season's growth took place a month later than it did on spurs on the same trees.

The development of the flower parts on the axillary buds was more rapid than in the spur buds because by the 18th August, the buds of all three series showed sepal but no petal primordia (see Fig. 7, *c*). By the end of the growing season there was little or no difference in the stage of development reached by the buds of all series.

It is pointed out that the year 1928 was a favourable one for flower bud formation at Long Ashton by reason of the dry summer and that this may have in some measure been responsible for the earliness of flower bud initiation. In any case it would appear that flower bud formation may be expected to begin at the end of June or during early July and that conditions prevailing at this time and earlier are very important in that they affect the amount and vigour of the flowers that are initiated. It is also seen that fruit thinning at a later date than this can have little effect upon the amount of flower bud initiated that year, because the critical time has already passed.

In determining orchard practice and management, it is evident that the period May-June is very important and that conditions prevailing during the preceding autumn, such as crop, rainfall and soil conditions may give hang-over effects which it is necessary to have in mind when determining orchard management and cultural treatments in spring.

The results may be summarised as follows :

Date.	Series I.	Series II.	Series III.
6.6.28	Purely vegetative		
13.6.28	do.		
25.6.28	Apex flattened		
2.7.28	First signs of primordia	First signs of primordia	
9.7.28	Primordia developing		
22.7.28	First signs of sepals	First signs of sepals	
4.8.28	Development continued		First signs of primordia
18.8.28	Sepals differentiated		Sepal primordia

The authors are indebted to Dr. Skene of the Department of Botany, The University, Bristol, for suggesting some co-operative activity with his department ; and for his interest in this work. Also to The Director of the Long Ashton Research Station for facilities and material.

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NOTES ON FIGURES.

Fig. 1. First Series, June 18th, 1928.

The growing point is enlarged and no evidence of flower primordia can be seen.

Fig. 2. First Series, June 25th, 1928.

Here the apex is seen to be broader and flatter than in Fig. 1.

Fig. 3. First Series, July 2nd, 1928.

In this section the first signs of primordia are seen, as small projections.

Fig. 4. Second Series, July 2nd, 1928.

As in Fig. 3, the primordia are developed.

Fig. 5. Second Series, July 9th, 1928.

The flower primordia at one side of the apex is much larger than in the previous week.

Fig. 6. Third Series, August 4th, 1928.

This shows flower primordia in an early stage of development.

Fig. 7. First Series, August 18th, 1928.

This shows the flower primordia at a more advanced stage, the sepals being well developed.

Fig. 8. Third Series, August 18th, 1928.

This bud shows the sepals being differentiated.

Fig. 9. Second Series, July 16th, 1928.

In Fig. 8 the third picking of the third series, the sepals are differentiated, but in this section no evidence of sepals can be seen.

(*Received* 26/10/29.)

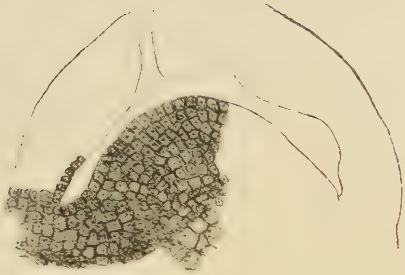

FIG. 1. First Series. June 18th, 1928.

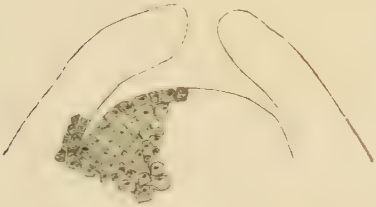

FIG. 2. First Series. June 25th, 1928.

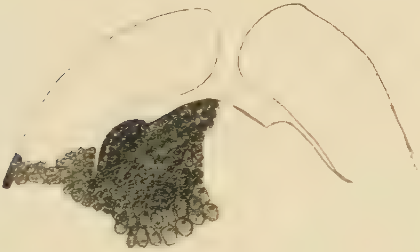

FIG. 3. First Series. July 2nd, 1928.

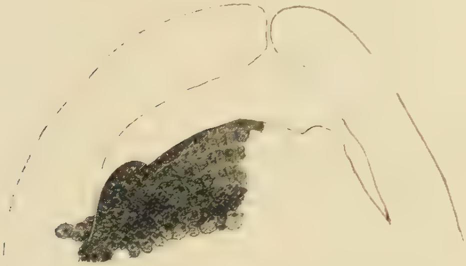

FIG. 4. Second Series. July 2nd, 1928.

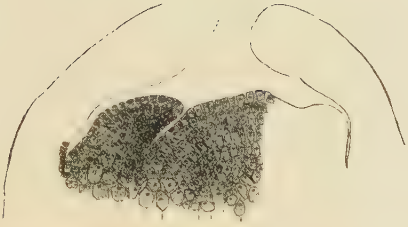

FIG. 5. Second Series. July 9th, 1928.

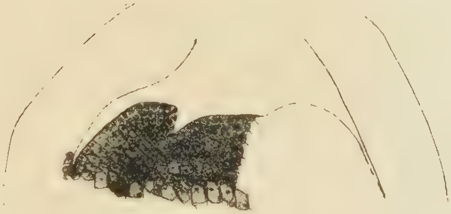

FIG. 6. Third Series. August 4th, 1928.

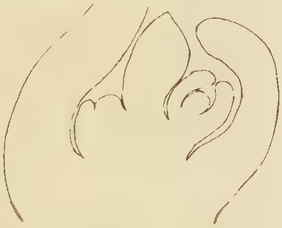

FIG. 7. First Series. August 18th, 1928.

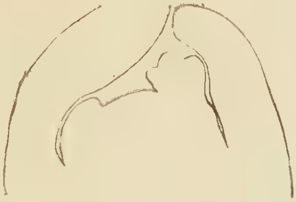

FIG. 8. Third Series. August 18th, 1928.

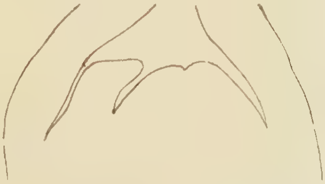

FIG. 9. Second Series. July 16th, 1928.

THE TIME OF FLOWER-BUD DIFFERENTIATION OF THE APPLE.

For description of figures see text.

THE GAS STORAGE OF FRUIT.

*II. OPTIMUM TEMPERATURES AND ATMOSPHERES.

By FRANKLIN KIDD and CYRIL WEST.
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Introduction.

In the present communication it is proposed to take up the study of the effects of storing apples in atmospheres of regulated composition from the point at which it was left in the first paper in this series*. In that paper it was stated that an artificial atmosphere containing less oxygen and more carbon dioxide than are normally present in air retards the natural ripening processes of certain varieties of apples, in particular the Bramley's Seedling variety. The experiments, however, did not provide precise information as to the optimum temperatures and gas concentrations.

The next step in this investigation, therefore, was a series of storage trials to ascertain the interaction of the three variables (1) temperature, (2) concentration of carbon dioxide, and (3) concentration of oxygen in the storage of Bramley's Seedling apples.

In the previous paper (l.c.) attention was directed to the fact that the effects produced by any given concentrations of oxygen and of carbon dioxide vary with temperature. It seemed also not unlikely that the effects produced at any given temperature and with any given concentration of carbon dioxide varied with the concentration of oxygen used. Similarly with different concentrations of carbon dioxide the effects of any given temperature and oxygen concentration were not the same. The three variables with which we are concerned in the present paper must therefore be regarded as being interdependent as regards their effects upon the ripening processes of the apple fruit.

Since practical interest lies in the magnitude of these effects and since there is so much variation in fruit from year to year and from orchard to orchard, it appeared desirable to include as many combinations as possible of temperature, oxygen concentration and carbon dioxide concentration in a simultaneous series of experiments for which strictly comparable samples of apples could be employed. The equipment required to carry out such a survey is not inconsiderable, and even with the resources of the Low Temperature Research Station available it has only been possible so far to carry it out on a small scale.

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* F. Kidd and C. West. Gas Storage of Fruit. Special Report No. 30, Food Investigation Board, London, 1927.

THE STORAGE CONDITIONS.

Twenty-three bushels of Bramley's Seedling apples were gathered on the 4th October, 1926, from an orchard on a chalk soil near Cambridge and were brought into the laboratory on the same day. From this supply 141 comparable trays, each holding twenty-three fruits, were made up in such a way that each tray contained one apple from each of the twenty-three bushels gathered. The following storage conditions were selected :—three temperatures, namely, 1°C. (34°F.), 5°C. (41°F.), 10°C. (50°F.), and at each of these temperatures ten different atmospheres, namely,

Gas Series 1-4 : 5% oxygen with 0%, 5%, 10% and 15% carbon dioxide.
Gas Series 5-8 : 10% oxygen with 0%, 5%, 10% and 15% carbon dioxide.
Gas Series 9 : 15% oxygen with 15% carbon dioxide.
Gas Series 10 : Air.

In all, therefore, the effects of thirty different storage conditions were compared on samples of apples as nearly as possible comparable when put into store. Four trays of fruit were stored under each condition.

The storage conditions were obtained in the following way. Three cabinets, each containing ten gas-tight compartments, were specially designed and constructed. These were placed in constant-temperature rooms at the L.T.R.S. maintained at 1°, 5° and 10°C. respectively. Atmospheres of the desired composition were made up in ten gasometers of approximately 60 cubic feet capacity, the oxygen, nitrogen and carbon dioxide being supplied from pressure cylinders. From each gasometer a pipe was led, branching to each of the three constant-temperature rooms and there connecting to the inlet pipes of the compartments of the cabinets. From the opposite side of each compartment the gas mixtures were led away to the outside of the building. The composition of each storage atmosphere was maintained by constant ventilation of the storage chambers with the artificial mixtures from the gasometers. The rate of ventilation was adjusted to allow approximately a 1% difference in the concentrations of oxygen and carbon dioxide between the actual storage atmosphere and the incoming gas mixture.

The cabinets were constructed of five-ply wood with the exception of the partitions and fronts which were of Kauria pine. In spite of the most careful cabinet-making the compartments were found to be far from gas-tight until all the woodwork had been treated with vaseline which was melted in with a hot iron. This treatment was followed by a coating of odourless mineral oil. The removable fronts were bedded into position with vaseline to ensure gas-tight joints.

From the above it will be seen that the conditions common to all experiments were, in the first place, the avoidance of stagnation by a slow ventilating current of gas uncontaminated with volatile products from the fruit; secondly, the presence of mineral oil in close proximity to the fruit. Under these circumstances mineral oil wrappers for the prevention of scald, as advocated in our previous Report, for use when "gas" storage is conducted in stagnant atmospheres, were not thought to be necessary and were omitted.

With the appliances to hand it was found impossible to control accurately the humidity of the atmospheres. In order to avoid saturation and to obtain approximately 95% relative humidity in all cases, the incoming ventilating currents of mixed gases were bubbled through tubes containing solutions of calcium chloride. By the end of March the loss of water by evaporation amounted to about 5% of the original fresh weight of the fruit at 10°C. and 5°C. The fruit stored at 1°C. had lost only 4% of its original fresh weight.

The thirty storage compartments were closed and the "gas" conditions established on the 23rd of October, that is, nineteen days after the fruit was gathered.

The concentrations of oxygen and of carbon dioxide in the storage compartments were checked by frequent analyses. Two typical gas records are shown in Figure 1. The oxygen and carbon dioxide conditions were not quite constant neither did they run quite as planned. The average gas conditions for the eight months of storage in the thirty different storage compartments are shown in Table I.

TABLE I.

Showing average gas concentrations during experiments.

Gas series.	Required concentrations		Actual Concentrations.			
			Oxygen (in gasometers).	Carbon dioxide (in storage compartments).		
	O_2	CO_2	%	A. (1°C.). %	B. (5°C.). %	C. (10°C.). %
1	5	0	6.4	1.0	1.4	1.6
2	5	5	6.4	5.1	5.7	5.2
3	5	10	6.1	10.8	11.9	10.1
4	5	15	6.3	14.9	16.9	14.2
5	10	0	11.0	1.1	1.5	2.1
6	10	5	10.6	5.5	6.1	6.3
7	10	10	10.6	10.3	11.6	9.9
8	10	15	10.9	15.9	16.9	14.1
9	15	15	15.5	15.9	16.6	14.6
10	—	—	—	0.4	1.2	—

The cabinets were opened and the stored fruit examined for wastage, colour change, taste and general condition at monthly intervals, the dates being 30th of November, 4th of January, 2nd of February, 23rd of March, 22nd of

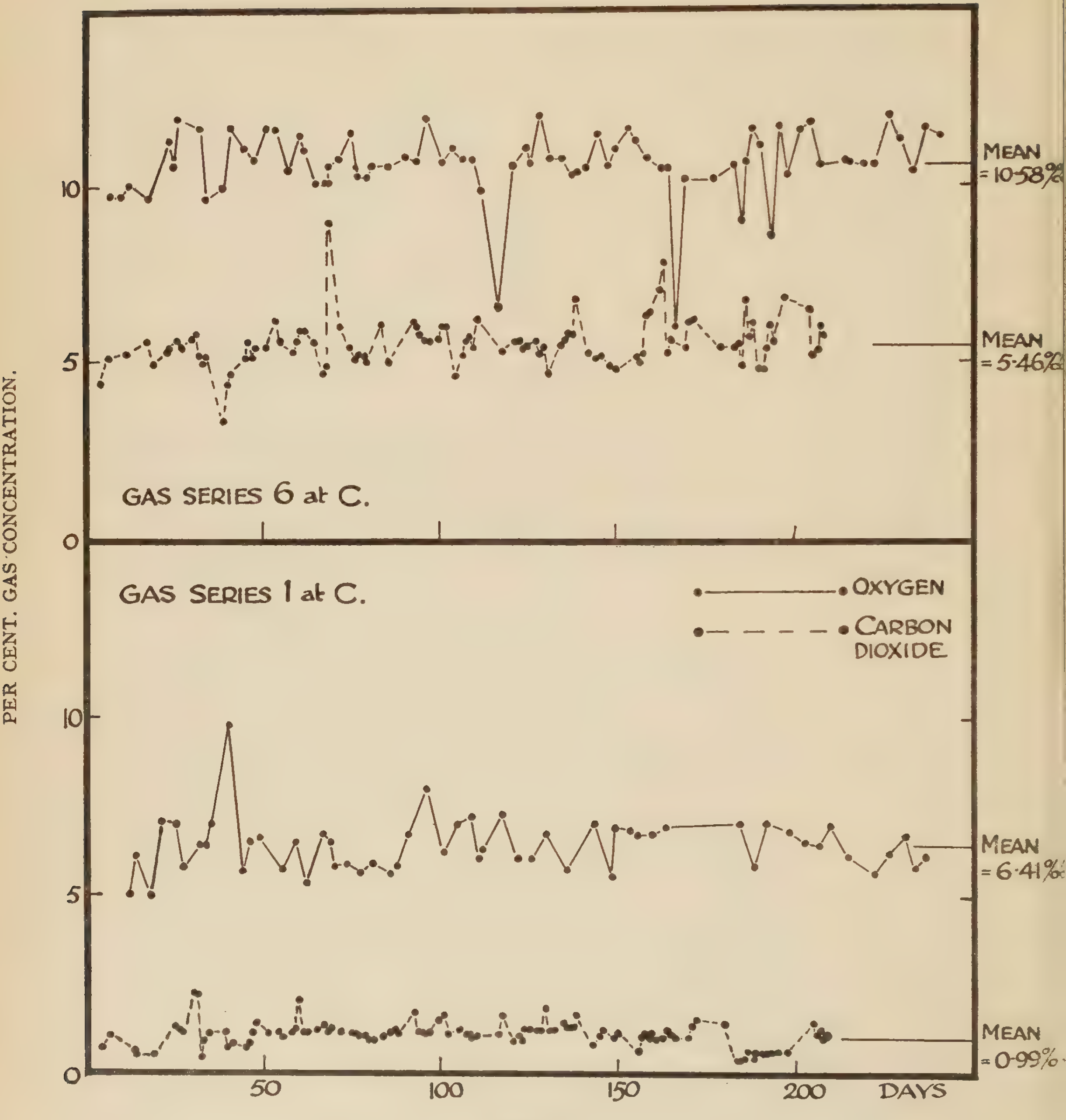
PER CENT. GAS CONCENTRATION.
GAS SERIES 6 at C.
10
5
0
MEAN =10·58%
MEAN =5·46%
GAS SERIES 1 at C.
OXYGEN
CARBON DIOXIDE
10
5
0
MEAN =6·41%
MEAN =0·99%
50
100
150
200
DAYS

Fig. I.

April, 23rd of May and 22nd of June. The results obtained under the different storage conditions are described in the following sections dealing respectively with effects on commercial storage life, with effects on the colour change from green to yellow, and with effects on low temperature internal breakdown.

EFFECTS ON COMMERCIAL STORAGE LIFE.

Commercial storage life is defined as the interval of time between the storage date of the fruit and the development of 10% wastage in the store. The total percentage wastage to date observed at each examination is plotted against time and the most probable curve drawn through the points. One can then judge with an accuracy depending on the number of observations and the size of the samples stored the commercial storage life of a much larger quantity of fruit.

The wastage at 1°C. was due entirely to the development of low temperature breakdown in the green, unripe fruit. The wastage at 5°C. and 10°C. was due entirely to fungal rotting. No brownheart occurred.

Fungal rotting was first observed in the air-stored controls at 10°C. in January. The first signs of low temperature breakdown at 1°C. occurred in February. The breakdown was then not detectable at the surface of the fruit, but was visible on cutting. Scald developed in certain cases late in the storage life of the fruit, when wastage from internal breakdown or fungal rotting had exceeded 10%.

The results as regards commercial storage life are summarised in Tables II. and III.

TABLE II.

Duration of commercial storage life (in weeks) in various gas mixture at different temperatures.

Gas mixtures (Approximate values; for actual values, see Table I.)			Commercial storage life (in weeks).			$\frac{\text{Life duration at } 5^\circ \text{ C.}}{\text{Life duration at } 10^\circ \text{ C.}}$
Gas series.	Oxygen. %	Carbon dioxide. %	1°C.	5°C.	10°C.	
1	5	0	20	26	17	1.5
2	5	5	19	34	21	1.6
3	5	10	18	36	21	1.7
4	5	15	15	37	22	1.7
5	10	0	23	24	16	1.5
6	10	5	23	34	22	1.5
7	10	10	21	39	26	1.5
8	10	15	17	38	21	1.8
9	15	15	15	36	21	1.7
10	21	0(air)	24	23	14	1.6

TABLE III.

Efficiency of various gas mixtures as compared with air at different temperatures.

Gas mixtures (Approximate values; for actual values see Table I.)			Efficiency of gas mixtures. Air = 1.0.		
Gas series.	Oxygen. %	Carbon dioxide. %	1°C.	5°C.	10°C.
1	5	0	0.8	1.1	1.2
2	5	5	0.8	1.5	1.5
3	5	10	0.7	1.6	1.5
4	5	15	0.6	1.6	1.6
5	10	0	1.0	1.0	1.1
6	10	5	1.0	1.5	1.6
7	10	10	0.9	1.7	1.9
8	10	15	0.7	1.7	1.5
9	15	15	0.6	1.6	1.5
10	21	0 (air)	1.0	1.0	1.0

In the first of these tables the duration of commercial storage life under each of the thirty different conditions of storage is shown. In the second table the efficiency of each gas mixture as compared with air storage at the same temperature is shown, the figures indicating how much longer or shorter was the commercial storage life under the controlled gas conditions than in air.

A glance at these tables at once reveals the outstanding results of the whole set of trials. They may be summarised as follows :—

1. At 1°C. the controlled artificial atmospheres are in all cases less efficient than air. Low temperature internal breakdown is accelerated by atmospheres containing more carbon dioxide and less oxygen than air. Within the limits investigated, reduced oxygen concentrations accelerate breakdown whether carbon dioxide is present or not. Increased carbon dioxide concentrations accelerate breakdown with any concentration of oxygen.

2. At 5°C., which is above the limit for low temperature breakdown (i.e. 3·5°C. in the case of the Bramley's Seedling varieties), and at 10°C. the controlled artificial atmospheres are in all cases more efficient than air.

The degree of efficiency shown by any given concentration of carbon dioxide depends both upon temperature and upon the oxygen concentration.

The retarding effect upon ripening produced by reduced oxygen concentrations in the storage atmosphere is not so great as that produced by increased concentrations of carbon dioxide.

The interdependence of the three variables, oxygen, carbon dioxide and temperature, in their effects upon storage efficiency, is illustrated in the following diagram (Fig. II.) which is based upon the data presented in Table III. This

DIAGRAM ILLUSTRATING HOW RELATIVE EFFICIENCY OF ATMOSPHERES CONTAINING CO_2 DEPENDS ON TEMPERATURE AND OXYGEN CONCENTRATION.

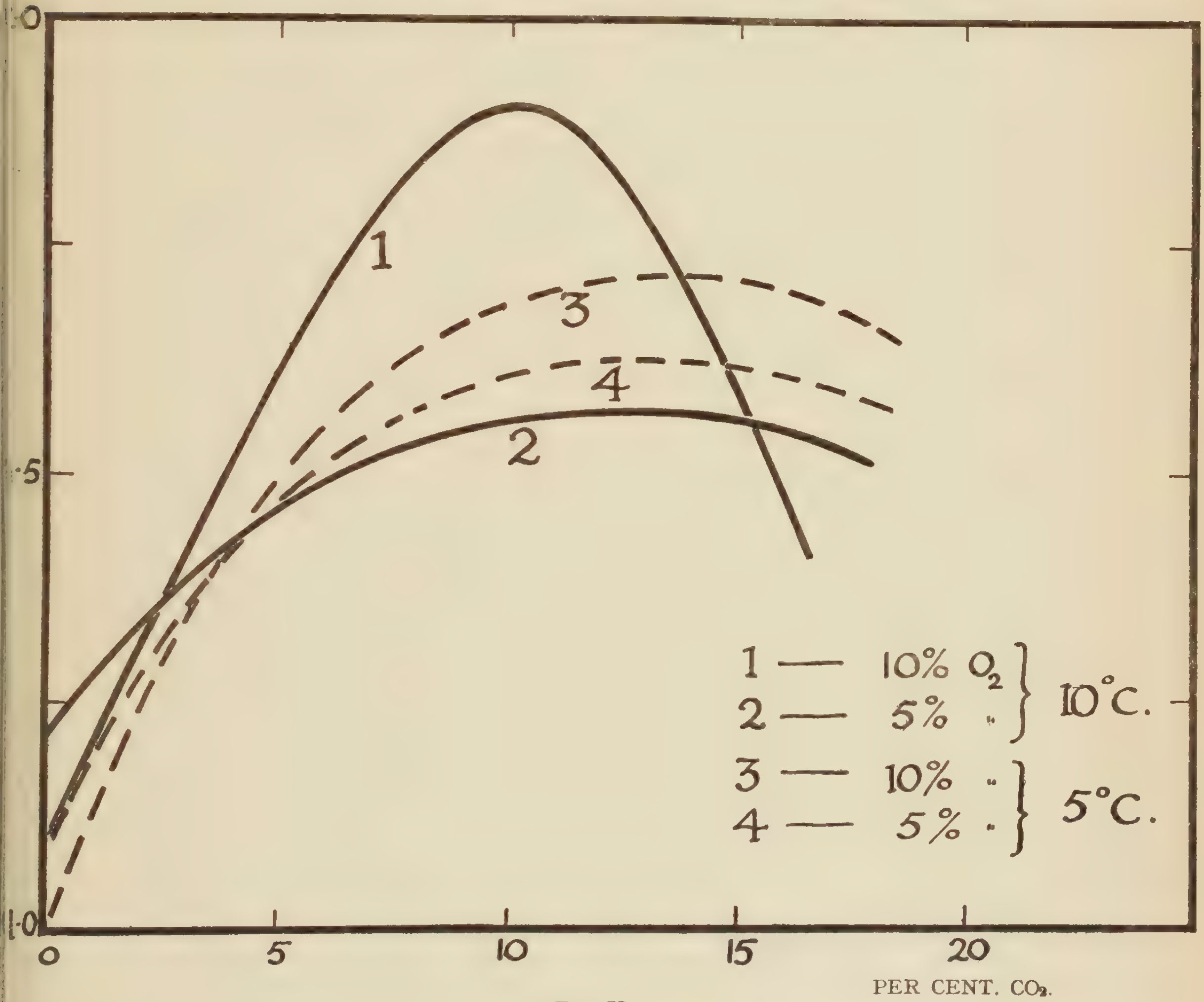

FIG. II.

diagram illustrates, as far as it can be stated at present, how the relationship between storage efficiency and carbon dioxide content of an atmosphere depends upon temperature and oxygen concentration. More exact work with larger samples will be needed to confirm these relations. The diagram indicates also that it is important to ascertain the effects of still higher concentrations of carbon dioxide in the storage atmosphere.

3. From a practical point of view the most efficient combination of conditions is clearly a temperature of 5°C. with an atmosphere containing 10%-15% of carbon dioxide and about 10% of oxygen. The oxygen apparently need not be very exactly regulated as between 5% and 15%. The regulation of the temperature on the other hand is most important.

With this combination of controlled conditions the results obtained as regards commercial storage life are 1.5 times better than the best possible by the use of controlled temperature alone (i.e. cold storage).

It remains to be determined whether one could go closer to the limiting temperature for low temperature breakdown (i.e. 3.5°C.) without danger.

EFFECTS ON THE CHANGE OF GROUND COLOUR FROM GREEN TO YELLOW.

At each examination the colour of the fruit under each storage condition was classified as deep green, green, yellowish green, slightly yellow, green yellow, yellow green, yellow, or deep yellow. This method of observing colour change clearly needs much improvement, and attention has since been devoted to the problem of colour standards and to a systematic study of the whole question of colour change during ripening and in stored fruit.

The observations that were made in the present series of experiments enable one to gain a fairly clear idea of the broad effects of the various conditions investigated upon the yellowing of the Bramley's Seedling apple.

It appears that at 10°C. the effect of 15% carbon dioxide is nearly to double the time taken to reach a given stage of yellowing and that the percentage of oxygen over the range studied does not markedly influence this ratio.

The effect of oxygen concentration upon the rate of yellowing was as pronounced as that of carbon dioxide. With 5% oxygen the fruit at 10°C. took about twice as long to yellow as in air (21% oxygen).

Practical interest attaches to the fact that the ratio between rate of colour change and length of commercial storage life is not the same under different storage conditions. It appears that in general atmospheric control not only extends the commercial storage life of the fruit, but to an even greater extent retards yellowing. This point is made clear in the following table.

TABLE IV.

Storage condition.	Colour of fruit at end of commercial storage life (i.e. by the time 10% wastage had developed).
Air at 10°C.	Yellow : 14 weeks.
Air at 5°C.	Yellow : 23 weeks.
Air at 1°C.	Yellowing : 24 weeks.
15% CO_2 : 10% O_2 : at 10°C.	Deep green : 21 weeks.
at 5°C.	Deep green : 38 weeks.
at 1°C.	Deep green : 17 weeks.
10% CO_2 : 10% O_2 : at 10°C.	Greenish yellow : 26 weeks.
at 5°C.	Deep green : 39 weeks.
at 1°C.	Deep green : 21 weeks.
5% CO_2 : 10% O_2 : at 10°C.	Slight yellowing : 22 weeks.
at 5°C.	Deep green : 34 weeks.
at 1°C.	Deep green : 23 weeks.
10% CO_2 : 5% O_2 : at 10°C.	Slight yellowing : 21 weeks.
at 5°C.	Deep green : 36 weeks.
at 1°C.	Deep green : 18 weeks.
5% CO_2 : 5% O_2 : at 10°C.	Slight yellowing : 21 weeks.
at 5°C.	Deep green : 34 weeks.
at 1°C.	Deep green : 19 weeks.

BEHAVIOUR OF THE FRUIT AFTER REMOVAL TO AIR.

On June 23rd, that is, after thirty-four weeks in storage, samples of sound fruit were removed to air from gas-series Nos. 2, 3, 4, 7, and 8 at 5°C. These apples were then quite green, firm and perfect in appearance and flavour. At the prevailing summer temperatures they remained in excellent condition for a further six weeks, after which they were all used for culinary purposes.

EFFECTS ON DEVELOPMENT OF LOW TEMPERATURE INTERNAL BREAKDOWN.

It has already been pointed out that at 1°C. all the artificial atmospheres tested were found to be less efficient than air, as shown by the earlier development of internal breakdown. The practical significance of this result lies in the fact that under present conditions of commercial practice carbon dioxide often accumulates in refrigerated fruit stores and in the holds of ships carrying apples.

The results revealed two other facts of interest. In the first place, it appeared that within the limits of the experiments, the presence of carbon dioxide was more injurious to the fruit than a reduction in the concentration of oxygen. The worst results obtained were with a combination of a high concentration of carbon dioxide and a low oxygen concentration.

In the second place, it was found that a reduction in the concentration of oxygen, while accelerating the development of internal breakdown, actually decreased the susceptibility of the fruit to this disease. The presence of carbon dioxide, on the other hand, appeared to increase it. For example, in the presence of 5% oxygen and 0% carbon dioxide (gas-series 1) the indication was that about 50% of the apples would never develop breakdown. In air possibly 20% of the apples would remain immune from this disease. When carbon dioxide was present every fruit broke down.

From these facts it would appear that the low temperature limit for the cold storage of apples susceptible to low temperature internal breakdown will depend upon the composition of the atmosphere of the store. Further investigation is needed to answer this question.

EFFECTS ON THE CHEMICAL CHANGES TAKING PLACE IN THE FRUIT.

A separate experiment was carried out to examine this question. Samples of Bramley's Seedling apples were used strictly comparable to those employed in the main storage experiment described above. These were stored at 10°C. in three different artificial atmospheres. The following were used : (1) 21% O_2 and 0% CO_2 (i.e. Air) ; (2) 10% O_2 and 9% CO_2 ; and (3) 10% O_2 and 0% CO_2. A comparison between (1) and (3) should show the type of effects due to reduced oxygen concentration : and comparison between (2) and (3) the type of effects due to increased carbon dioxide concentration. Samples were removed from storage at approximately monthly intervals and the losses in cane sugar, total sugar, acid and total dry matter determined.

The results indicate that the average rate of loss of carbohydrates by respiration was between 1.2 and 1.4 times faster in air (21% O_2) than in 10% O_2 : and between 1.35 and 1.55 times faster in the absence of carbon dioxide than in the presence of 10% of this gas.

It is interesting to compare these results with the relative durations of commercial storage life observed in these three cases (Table V.).

TABLE V.

Storage conditions.	Relative average rate of loss of dry material.	Inverse of average rate of loss.	Relative length of storage life.
21% O_2 (Air)	1.00	1.00	1.00
10% O_2	0.77	1.30	1.15
10% O_2 and 9% CO_2 ..	0.53	1.90	1.85
10% O_2	1.00	1.00	1.00
10% O_2 and 9% CO_2 ..	0.69	1.45	1.60

From the above table it appears that the effect of reducing the concentration of oxygen is rather more marked on the rate of loss of dry material than it is upon the duration of life. On the other hand the effect of carbon dioxide is more marked on storage life than it is upon the rate of loss of dry material. This result is attributed to the fact that carbon dioxide exerts a retarding effect not only upon the rate of respiration of the fruit, but also upon the germination and growth of the fungi responsible for rotting.

The chemical results confirmed the interesting fact, noted in our previous paper (l.c.), that the changes occurring are not all proportionately retarded by artificial atmospheres and that in the early stages of storage cane sugar, for example, actually disappears faster in the presence of carbon dioxide than it does in air. The present results also give some indication that during the early stages of storage cane sugar is lost more rapidly in 10% oxygen than in air.

The rate of acid loss does not appear to be markedly affected either by reduction in oxygen concentration or by the presence of 9% carbon dioxide.

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EXPERIMENTS ON THE STORAGE OF PEARS IN ARTIFICIAL ATMOSPHERES.

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INTRODUCTION.

It has been shown by Kidd and West (1) that the ripening of pears practically ceases in nitrogen, but that this treatment cannot be prolonged indefinitely without injurious results. Nevertheless, by excluding oxygen from the storage atmosphere for a period and subsequently readmitting air, they found that practically normal ripening (slightly retarded) was obtained, the storage life of the pear being prolonged to the extent of the period of oxygen exclusion plus the slight retardation in air ripening subsequently.

Thomas (2) has reported the effects of holding apples in nitrogen, in carbon dioxide and in mixtures of carbon dioxide and oxygen. He found that alcohol and aldehyde were produced in all cases, but in nitrogen the alcohol aldehyde ratio was 50/1 whereas in mixtures of carbon dioxide and oxygen the ratio was 2/1. No attempt was made to determine the ratio in mixtures of nitrogen and carbon dioxide.

Harley and Fisher (3) suggests that acetaldehyde is a possible causative agent in the production of scald and breakdown in pears, acetaldehyde being found in large quantities in scalded and broken down tissue. A correlation was found to exist between the severity of the breakdown and the concentration of acetaldehyde in the tissues. That acetaldehyde in certain concentrations may be toxic to pear tissues was demonstrated by exposing the fruit to acetaldehyde vapour or by injecting dilute solutions of acetaldehyde in water into the tissues. He points out however that his observations do not definitely prove that acetaldehyde is the cause of breakdown in stored pears.

In the light of the above investigations it was decided to conduct experiments with the following objects in view :—

1. To repeat the experiments of Kidd and West.
2. To determine the optimum temperature for the Kidd-West effect.
3. To investigate the influence of the presence of CO_2 on this effect.
4. To study quantitatively the phenomenon of acetaldehyde production, (a) under conditions of oxygen shortage, (b) during physiological (scald and core) breakdown, and (c) in relation to the quantity of carbon dioxide produced.

The experiments described in the present paper were carried out with two varieties of pears—Conference and Beurre Clairgeau, the latter variety being particularly susceptible to deep scald in cold storage.

EXPERIMENTS WITH CONFERENCE PEARS.

I. Oxygen excluded from the storage atmosphere but carbon dioxide in various concentrations present.

The pears used in this series of experiments had already been in cold storage for four weeks. The fruits were hard, but had begun to sweeten and to yellow.

Three large glass containers, each holding about twenty pears, were filled with nitrogen; three with 95% nitrogen and 5% carbon dioxide; three with 90% nitrogen and 10% carbon dioxide; and three with 85% nitrogen and 15% carbon dioxide. They were then placed in store at 3°C. An exactly similar series was set up at the same time at 10°C. and at 18°C. Controls in air were stored at these three temperatures.

Analyses of the atmospheres in the glass containers were made every day to ascertain the extent to which the carbon dioxide content had increased as the result of the respiratory activity of the fruit. After these analyses the original composition of the atmosphere was restored by passing in the requisite amount of pure nitrogen. The daily accumulation of carbon dioxide in addition to the amount originally present was of course greater at the higher temperatures. At 18°C. it amounted to about 15%, at 10°C. to about 10% and at 3°C. to about 5%. The actual amount in each case varied to a smaller extent in relation to differences in the volume of the different containers and in the weight of pears in each.

The results obtained at 18°C. showed that there was no marked difference in the fruit stored in the different atmospheres of nitrogen and carbon dioxide. After a week, "gas"-stored fruits were harder and greener than the air-stored controls, but 40% of the "gas"-stored fruit showed core breakdown. Apparently sound fruit removed at this time developed core breakdown subsequently in air.

On the second examination after two weeks storage at 18°C. all the fruit from the artificial gas mixtures was found to have developed core breakdown and a peculiar taste. In some cases the cortical flesh also was affected. Penetrometer tests showed, that in spite of the core breakdown present, the "gas"-stored fruit was harder than the controls.

The pears stored at 10°C. in the artificial atmospheres described above were examined after ten days. They appeared to fall into two classes. One class consisted of fruit from atmospheres in which the concentration of carbon dioxide had never been above 10%. This fruit was harder and greener than control fruit and showed no core breakdown. Moreover, it ripened normally in air but some time later than the control fruit kept in air from the outset.

The other class consisted of fruit from atmospheres in which the concentration of carbon dioxide had occasionally or throughout, exceeded 10%. In this class, none of the fruits ripened normally. Immediately, on removal from the artificial gas mixtures, some of the fruit was sound, being harder and greener than the control fruit, but some had already developed core breakdown. On further storage in air the sound fruit also developed core breakdown.

The results obtained in the series of experiments at 3°C. were in line with those at 10°C. (Tables I., II. and III. summarise the observations made in these three series of experiments.)

TABLE I.

Conference Pears stored at 18°C.

No. of days in storage.	In air.	In artificial atmosphere.
7	Good, hard, ripe.	40% affected with core breakdown. 60% normal but after exposure to air, core breakdown developed.
14	Mealy, due to over-ripeness.	98% affected with core breakdown. 2% normal but after exposure to air, core breakdown developed.

TABLE II.

Conference Pears stored at 10°C.

No. of days in storage.	In air.	In artificial atmospheres.
10	Good, hard, ripe.	20% affected with core breakdown. 80% normal, but developed core breakdown after further storage in air except in the case of fruit which had experienced less than 10 per cent. carbon dioxide (see below (1)).
20	Mealy, due to over-ripeness.	90% affected with core breakdown. 10% normal, but developed core breakdown after further storage in air.
26		(1) The fruit, which had experienced less than 10 per cent. carbon dioxide and which had been removed from the artificial atmosphere at the end of the tenth day, now ripe and showed no breakdown. Not quite as sweet as air control fruit examined previously.

TABLE III.

Conference Pears stored at 3°C.

No. of days in storage.	In air.	In artificial atmospheres.
21	Hard, ripe.	20% affected with core breakdown. 80% normal but developed core breakdown after further storage in air; except in the case of fruit, which had experienced less than 10 per cent. carbon dioxide. (see below (2)).
28	Mealy, due to over-ripeness.	88% affected with core breakdown. 12% normal but developed core breakdown after further storage in air.
40		(2) Fruit, which had experienced less than 10 per cent. carbon dioxide and which had been removed from the artificial atmospheres at the end of the twenty-first day, now ripe. Condition quite normal, no breakdown, but not as sweet as air control fruit examined on the twenty-eighth day.

The general outcome appeared to be that at all temperatures tested, harmful results followed storage in oxygen-free atmospheres, containing more than 10% carbon dioxide. Short exposures, however, to oxygen-free atmospheres, containing less than 10% carbon dioxide, delayed ripening and prolonged the storage life of the fruit.

The best results were obtained with the pears, stored twenty-one days from the beginning of the experiment at 3°C. in an oxygen-free atmosphere, containing less than 10% carbon dioxide. These pears ripened six weeks from the date of storing as compared with four weeks in the case of the control fruits, stored in air throughout at the same temperature.

II. Both oxygen and carbon dioxide excluded from the storage atmosphere.

The Conference pears used in this series of experiments were riper than those used in the previous series, as they had been in cold storage some weeks longer prior to the setting up of the experiments. They were, however, still hard, though beginning to sweeten and to turn yellow.

Fruit was stored in gas-tight metal tanks, each tank holding about eighty pears. These tanks were filled with nitrogen, and soda lime was placed in them in order to absorb the carbon dioxide formed by the fruit. An equal number of pears was stored in air in open metal tanks. Four experiments were conducted, one at each of the following temperatures, 5°C., 10°C, 15°C. and 18°C. Fruits were taken from the experimental tanks at intervals and their condition and subsequent ripening in air was compared with that of the controls.

The course of events at all temperatures was broadly similar as regards the fruits stored in nitrogen. Very little change occurred in their apparent condition as judged by colour and hardness, but after a certain period—the length of the period varying with the temperature—fungal invasion commenced and showed itself as darkened and sunken areas on the skin, especially at the stalk end.

The time at which fungal invasion began to show itself at each temperature in nitrogen storage very approximately corresponded to the time at which the controls stored in air at these temperatures had reached full ripeness. When removed from nitrogen storage at this stage the experimental pears ripened normally in air, taking about the same time to ripen as the controls had previously done.

As is to be expected, it is at the lowest temperature that we obtain the greatest absolute extension of life both in air and in nitrogen-air storage. But it is interesting to note that the relative efficiency of nitrogen-air storage, that is to say, the ratio $\frac{\text{Time to ripen in nitrogen-air storage}}{\text{Time to ripen in air}}$ is greater at the lower temperatures. This may be due to the fact that fungal invasion of the pears in nitrogen is postponed relatively longer at the lower temperatures. Fig. 1 shows as nearly as can be determined from the data, (a) the time to ripen in air at different temperatures (Curve II.), (b) the time to onset of fungal invasion (Curve I.), and (c) the time to ripen, in the case of pears kept as long as possible without wastage in nitrogen and then removed to air at various temperatures (Curve III.).

Before proceeding to describe the next series of experiments, one further point needs comment. Short exposures to an atmosphere free from oxygen, for example two to four days at 18°C., and twelve days at 5°C., had little or no effect on ripening. Fruit, so treated, ripened finally at the same time as the controls. It must be concluded that the retarding effect of the nitrogen conditons did not become immediately operative. (Tables IV. to VII. summarise the observations made in this series of experiments.)

TABLE IV.

Condition of Conference Pears stored at 18°C.

No. of days in storage.	In air.	In nitrogen.	Behaviour after removal from nitrogen.
2	Hard.	Hard.	Fully mature on 9th day.
4	Hard.	Hard.	,, ,, 9th ,,
6	Hard.	Hard.	,, ,, 12th ,, not quite as sweet as controls.
9	Signs of over-ripeness.	Fungal invasion in 90%	

TABLE V.

Condition of Conference Pears stored at 15°C.

No. of days in storage.	In air.	In nitrogen.	Behaviour after removal from nitrogen.
2	Hard.	Hard.	Fully mature on 12th day.
4	Hard.	Hard.	,, ,, 12th ,,
6	Hard.	Hard.	,, ,, 12th ,,
8	Almost fully mature.	Hard.	,, ,, 15th ,, not quite as sweet as controls.
10	Fully mature.	Hard. Fungal invasion in 10%.	
12	Signs of over-ripeness.	Hard. Fungal invasion in 80%.	

TABLE VI.

Condition of Conference Pears stored at 10°C.

No. of days in storage.	In air.	In nitrogen.	Behaviour after removal from nitrogen.
2	Hard.	Hard.	Fully mature on 16th day.
4	Hard.	Hard.	,, ,, 16th ,,
6	Hard.	Hard.	,, ,, 17th ,,
8	Hard.	Hard.	,, ,, 17th ,,
10	Almost fully mature.	Hard.	,, ,, 19th ,,
12	Fully mature.	Hard.	,, ,, 21st ,, not quite as sweet as controls.
14	Becoming soft.	Hard. Fungal invasion in 20%.	
16	Signs of over-ripeness.	Hard, in 80%.	

TABLE VII.

Condition of Conference Pears stored at 5°C.

No. of days. in storage.	In air.	In nitrogen.	Behaviour after removal from nitrogen.
12	Hard.	Hard.	Fully mature on 28th day.
21	Almost fully mature.	Hard.	,, ,, 38th ,,
28	Over-ripe, some rotting.	Hard.	,, ,, 42nd ,, just as sweet as controls.
35		Hard. Fungal invasion in 50%. 50% hard, good.	Fully mature on 42nd day. just as sweet as controls.

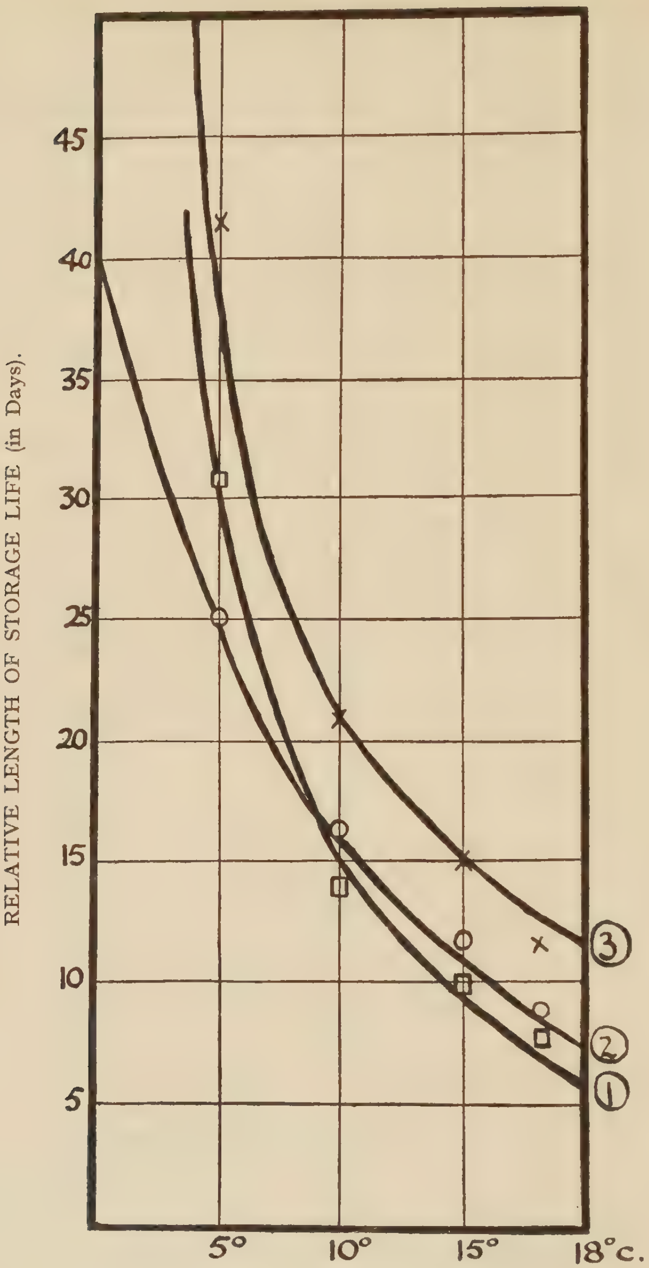

Fig. I.

STORAGE TEMPERATURE.

Curve 1.—Relation between temperature of Storage and length of Storage life in Nitrogen.

Curve 2.—Relation between temperature of Storage and length of Storage life in Air.

Curve 3.—Maximum life obtained by storing in Nitrogen till just before fungal invasion; then removing to air to ripen.

EXPERIMENTS WITH BEURRE CLAIRGEAU PEARS.

I. Oxygen excluded from storage atmosphere but carbon dioxide in various concentrations present.

In this series of experiments a different variety of pear, namely Beurre Clairgeau, was used. These pears had been in cold storage for about three weeks. They are a later variety than the Conference, and were still hard and green. They showed, in fact, no obvious difference in appearance or hardness from that of freshly gathered hard green fruit.

A number of glass containers, each containing about thirty pears were set up as follows. Each glass container had an inlet and exit tube, which could be sealed. Artificial atmospheres were established by running in nitrogen and carbon dioxide from cylinders until the normal atmosphere was displaced and the desired percentage of carbon dioxide in nitrogen was obtained. The percentage of carbon dioxide rose each day, owing to the activity of the enclosed fruit in producing carbon dioxide anaerobically, but each day it was brought back to its original value by running in nitrogen to displace some of the enclosed atmosphere. The measurements of carbon dioxide were made by the katharometer and checked by analysis with a Haldane's apparatus. They may be considered accurate to about 0.5%.

Experiments were conducted at three temperatures respectively, 5°C., 10°C. and 15°C. Owing, however, to unforeseen circumstances, ten days after starting the experiments, it was found necessary to raise the temperature in all cases. Pears stored at 5°C. were raised to 15°C., those at 10°C. to 18°C., and those at 15°C. to 22.5°C.

The following tables (VIII. to X.) give the details as regards the artificial atmospheres tested.

TABLE VIII.

Temperature 5°C. for ten days, then raised to 15°C.

No. of glass containers.	Artificial atmosphere re-established each day.		Maximum concentrations of CO_2 reached in each container at	
	CO_2	Nitrogen.	5°C.	15°C.
	%	%	%	%
3	0	100	13.9	26.1
			9.8	16.3
			15.8	27.2
3	5	95	16.8	27.8
			10.8	18.8
			9.9	16.9
3	10	90	21.8	35.1
			20.1	31.2
			21.4	32.4

TABLE IX.

Temperature 10°C. *for ten days, then raised to* 18°C.

No. of glass containers.	Artificial atmosphere re-established each day.		Maximum concentrations of CO_2 reached in each container at	
	CO_2	Nitrogen.	10°C.	18°C.
	%	%	%	%
3	0	100	16.4	28.8
			14.5	23.1
			19.5	32.2
3	5	95	26.2	35.2
			16.1	25.9
			17.4	27.9
3	10	90	26.6	36.2
			24.7	31.2
			25.9	35.2

TABLE X.

Temperature 15°C. *for ten days, then raised to* 22.5°C.

No. of glass containers.	Artificial atmosphere re-established each day.		Maximum concentrations of CO_2 reached in each container at	
	CO_2	Nitrogen.	10°C.	18°C.
	%	%	%	%
3	0	100	27.4	39.0
			24.2	32.4
			26.1	34.1
3	5	95	28.7	39.1
			24.6	37.2
			21.1	30.7
3	10	90	28.9	38.7
			27.2	34.7
			27.6	35.2

From each of the above artificial atmospheric conditions, pears were removed every few days to air and their subsequent behaviour, as regards ripening and development of scald, was observed and compared with those, stored in air throughout, and with those remaining in the artificial atmospheres. Pears, removed to air during the first ten days of storage before the temperature was raised, were brought up to the higher temperature at the same time as the "gas"-stored lot, from which they had been taken and at the same time as the corresponding controls.

The Beurre Clairgeau pear, as previously stated, is one which is noted for scalding in cold storage, and the results obtained in these experiments were rather surprising. In the first place, practically all the air-stored control pears scalded severely whilst still hard, and never properly ripened. Thus, in less than three days, after the rise of temperature, control pears at 18°C. and 22.5°C. had all scalded severely. A similar result occurred at 15°C. a few days later. There were sixty pears in the control set at each temperature and in the end only two ripened normally. These two fruits were from the set, which had been stored at 5°C. for ten days and then subsequently at 15°C. As compared with the above the results obtained with the pears stored in artificial atmospheres are as follows. It will have been seen from the table above that only in the case of the glass containers stored at 5°C. for the first ten days before the temperature was raised, was a maximum daily accumulation of carbon dioxide above 10% avoided. Pears removed from these containers to air on the second, fourth, sixth, eighth and tenth day in storage ripened normally without scalding. Owing to the severe scalding of all the air-stored controls, as described above, it is not possible to make a strict comparison as regards " time to ripen " between these nitrogen-treated fruits, which ripened normally, and the untreated fruits which broke down with scald.

The actual results were :—

* Twelfth day.—Air controls breaking down with scald although still hard.

* Eighteenth day.—Fruit held in nitrogen for two, four, six days, ripe, normal flavour and sweet.

* Twenty-seventh day.—Fruit held in nitrogen for eight and ten days ripe, normal flavour and sweet.

In all cases except the above, the experimental fruit was exposed daily to concentrations of carbon dioxide above a critical minimum in the neighbourhood of 10%. In all these cases, though the fruit remained hard and green for a considerable time during storage in the artificial atmospheres, scalding took place after removal to air at about the same time as the controls stored in air throughout. When kept in the artificial atmospheres beyond the time at which the controls scalded, it was found that the fruit became much softer, and after removal to air the scalding proceeded extremely rapidly, sometimes appearing within five minutes. Prior to scalding, such pears, immediately on removal from the artificial atmosphere, showed no visible signs of injury to the epidermal and subepidermal layers, which macroscopically appeared normal in every way.

II. *Both oxygen and carbon dioxide excluded from the storage atmosphere.*

In parallel with the above series of experiments, at the same temperatures and with the same temperature changes after ten days storage from the beginning of the experiment, another series of experiments was carried out. In these experiments the atmosphere used was nitrogen alone, carbon dioxide being excluded by employing soda lime in the bottom of the containers to absorb this gas as fast as it was evolved by the fruit.

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* Temperature on tenth day raised from 5° C. to 15° C. in above cases.

Pears taken from nitrogen storage at intervals during the first ten days before the temperatures were raised, ripened normally and did not develop scald. The controls, as stated above, all developed scald between the twelfth and fifteenth day from the beginning of the experiment.

The removal of pears at intervals from nitrogen storage was continued after the storage temperatures had been raised. It was found that storage in nitrogen at 22.5°C. was followed by the development of scald when the fruit was removed to air to ripen. On the other hand, fruit, which had been raised from 10°C. to 18°C. or from 5°C. to 15°C., continued to ripen normally without scalding when removed at intervals to air. The ripening of this fruit was markedly delayed. Thus

Temperature raised from 10°C. *to* 18°C. *on tenth day.*

Twelfth day.—Air controls breaking down with scald.

Thirtieth day.—" Twenty day nitrogen " fruit ripe, normal flavour and sweet.

Temperature raised from 5°C. *to* 15°C. *on tenth day.*

Fifteenth day.—Air controls breaking down with scald.

Thirty-seventh day. " Twelve, sixteen, eighteen day nitrogen " fruit ripe, normal flavour and sweet.

Forty-third day.—" Twenty-one, twenty-five day nitrogen " fruit ripe, normal flavour and sweet.

After longer exposures to nitrogen at 15°C. and 18°C. than those shown above, the fruit failed to ripen normally and also developed scald after removal to air.

As a further check on the above results a single experiment was carried out on a larger scale.

The pears were stored in nitrogen in a large gas-tight metal tank at 15°C., with soda lime present to absorb the carbon dioxide formed by the fruit, and storage under these conditions was continued until the type of fungal rotting, noted above, began to appear. The pears at this time were still hard and green.

The results of this storage trial were as follows :—

Fruit stored in air throughout at 15°C. : Scald and breakdown after fifteenth day.

Fruit stored in air throughout at 5°C. : Scald and breakdown after thirty-fifth day.

Fruit stored in nitrogen for twenty-one days at 15°C., ripened in air at 5°C. Ripe after forty-nine days.

OBSERVATIONS ON ACETALDEHYDE FORMATION AND CARBON DIOXIDE PRODUCTION.

In view of the work of Thomas (2) measurements were made of the production of carbon dioxide and of acetaldehyde by pears during storage in nitrogen. Beurre Clairgeau pears, obtained from the same source as those employed in the experiments described above, were used. A high degree of accuracy was not attempted in the case of the determination of carbon dioxide production. The pears were enclosed in desiccators, which were filled with nitrogen. The volume and weight of the pears and the volume of the desiccator were known. The accumulation of carbon dioxide was determined by analysis and the desiccators were then refilled with nitrogen each day. At intervals, for the estimation of acetaldehyde, six pears were taken, cored, peeled and cut up into fine pieces. These were mixed well, and 150 grammes of the mixture was placed in a distilling flask and steam distilled. The condenser was cooled with ice water and the receivers with ice. Two receivers, containing 50 cc. of bisulphite solution, were used and the excess bisulphite was titrated with iodine.

The results, presented in Table XI., show that the amount of acetaldehyde formed under the conditions of the experiments bears a positive relation to the amount of carbon dioxide produced. For a given period of time the accumulation of acetaldehyde within the tissues is greatest at the highest temperatures. It is known that the rate of respiration increases with temperature, and it is interesting to note, therefore, that the acetaldehyde/carbon dioxide ratio is approximately the same at all temperatures.

TABLE XI.

No. of days in storage in nitrogen from beginning of experiment.	Gms. of CO_2 given off by 100 gms. of fruit.	Mgs. of acetaldehyde per 100 gms. of fruit.	Aldehyde/ CO_2 ratio.	Temperature.
Desiccator A. 19	29.0	11.6	.00040	15°C. raised to 22.5°C.
26	36.5	13.9	.00038	,, ,,
Desiccator B. 26	33.55	14.1	.00042	,, ,,
Desiccator C. 19	23.05	9.95	.00043	10°C. raised to 18°C.
Desiccator D. 19	23.45	10.5	.00044	,, ,,
Desiccator E. 20	17.25	7.96	.00046	5°C. raised to 15°C.
24	22.0	9.86	.00044	,, ,,
Desiccator F. 28	15.5	6.88	.00043	,, ,,

OBSERVATIONS ON ACETALDEHYDE FORMATION AND SCALD.

Harley and Fisher (3) have suggested that acetaldehyde may be the causative agent in the production of scald and breakdown. In view of this suggestion the acetaldehyde-content of the following classes of pears was determined.

(1) Pears, stored in air, which were showing severe scald ;

(2) Pears, stored in nitrogen, and more than 10% carbon dioxide, which subsequently scalded ;

(3) Pears, after long storage in nitrogen, carbon dioxide being excluded, which subsequently scalded ;

(4) Pears, after shorter storage in nitrogen, carbon dioxide being excluded, which subsequently ripened normally.

The figures obtained were as follows :—

Scalded. Class 1 0.3 mgs. of acetaldehyde per 100 gms. of tissue.

Scalded. Class 2. 6.88 to 14.1 acetaldehyde per 100 gms. of tissue (depending on temperature and length of exposure).

Scalded. Class 3. 8.5 to 22.7 of acetaldehyde per 100 gms. of tissue (depending on temperature and length of exposure).

Not Scalded. Class 4. 8.7 to 10.7 of acetaldehyde per 100 gms. of tissue (depending on temperature and length of exposure).

These results indicate that scalding is not due simply to the accumulation of acetaldehyde in the tissues.

DISCUSSION AND SUMMARY.

These experiments confirm the previous findings of Kidd and West. They indicate that, provided the temperatures are not too high and that more than 10% carbon dioxide in the atmosphere is avoided, it is possible, by excluding oxygen for a period, to extend the storage life of pears to the extent of 50% of the normal for any given temperature.

The practical application of this method should be further investigated.

The experiments also bring to light the new and surprising fact that the above treatment prevents the appearance of scald in susceptible varieties. It brings about some change in the fruit, following which normal ripening occurs instead of premature scalding, breakdown and failure to reach a stage fit for consumption.

Exclusion of oxygen and the consequent cessation of the normal respiratory oxidations set up conditions in which the carbohydrate metabolism of the fruit leads to the accumulation of acetaldehyde in the tissue. Accumulation of acetaldehyde in the tissue has been shown (3) to be associated with scald and core breakdown. The present experiments suggest that the chain of causation is more likely to be

breakdown, → waterlogging of tissue → anaerobic conditions with CO_2 accumulation → aldehyde formation rather than

aldehyde formation → toxic action → breakdown and waterlogging.

REFERENCES.

(1) *Kidd and West.* Nature, 3096. March, 1929, p. 315.

(2) *Thomas.* Biochem. Journ. Vol. XIX, No. 6, 1925, p. 927.

(3) *Harley and Fisher.* Journ. Agr. Res. Vol. 35, 1927, p. 983.

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THE OAK AND APPLE MILDEWS COMPARED.

MILDEW on oak trees was first recorded for this country in 1908. Since that time the fungus has become generally distributed and during recent years Oak Mildew has been a conspicuous feature of our woodlands. It is particularly prevalent on young oaks in coppices ; it also infects nursery trees as well as old established trees. As its ultimate effect is to check growth and to kill young twigs its control has become an afforestation problem of some considerable importance. This problem has been attacked and an article describing the Oak Mildew and its mode of parasitism, together with an account of experiments for its control, has appeared in a recent number of " Forestry, the Journal of the Society of Foresters of Great Britain."* The results described therein are of interest not only to " Foresters " but also to horticulturists and fruit-growers for, as shown by the authors, the problem is comparable with that which confronts the fruit-grower in combating Apple Mildew.

When the practical fruit-grower sees mildewed oaks in close proximity to his fruit he naturally enquires whether the oaks are a source of danger to his apples. It may be stated definitely that the answer is in the negative. Although the exact identity of the Oak Mildew is still under dispute mycologists are agreed that it is a species of *Microsphæra*, while the Apple Mildew is of the genus *Podosphæra*. The two are quite distinct therefore. The hosts of the Apple Mildew in Britain are the Sessile Oak (*Quercus sessiliflora*), the Pedunculate Oak (*Q. pedunculata*) and the beech.

One of the authors (Dr. Woodward) has recently made a detailed study of the mode of parasitism of the Apple Mildew and in the article referred to a comparison is drawn between the two parasites. Thus, in both fungi, the perfect (*perithecial*) stage is relatively unimportant for the perennation and the dissemination of the mildew. (In the Oak Mildew the perithecial stage has not yet been found in Britain, though it has been recorded from the Continent.) They pass the winter, in the form of mycelium, in the buds of the host and some of these buds grow out, the following year, as infected shoots (" primary infections ") from which numerous conidia are shed, and these cause " secondary infections " on other leaves. It is pointed out that the percentage of infected buds which give rise to infected shoots is less in the Oak Mildew than in the Apple Mildew but the former is stated to produce secondary infections far more readily. Infestation of oak trees by caterpillars is shown to be a factor rendering the trees more liable to secondary infection, for the young shoots which grow out following caterpillar damage are very susceptible to mildew.

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* WOODWARD, R. C., WALDIE, J. S. L., AND STEVEN, H. M. Oak Mildew and its Control in Forest Nurseries. *Forestry*, Vol. III, No. 1, 1929, pp. 38-56.

In common with other members of the *Erysiphaceæ* (the Powdery Mildews) the ravages of the Oak Mildew may be checked by the use of sulphur-containing sprays. In the experiments described in the paper good control was obtained with two proprietary brands of colloidal sulphur and with flowers of sulphur mixed with water, each at the rate of 2 or 4 lbs. in 100 gallons of water together with calcium caseinate or soft soap as a spreader. The authors summarize their results as follows : " These treatments secure that more than half of the plants are kept entirely free from mildew, height growth may be increased, and there is a great increase in the dry-weight of the plants. Bud infection is decreased, and the proportion of plants with good leaders is increased."

H.W.

The following *books have been received for review :* notices of these will appear in the next issue.

SEARS, F. C., Fruit Growing Projects. Messrs. MacMillan & Co., Ltd., N.Y. 7s. 6d.

CHANDLER, W.H., North American Orchards. Messrs. Lea & Febiger, Philadelphia. $4.50.

HOOD, G. W., Horticulture, Elementary and Practical. Henry Kimpton, 263, High Holborn, W.C. 15s.

WRANGHAM, S. D., Wasps, and how to destroy them. The Pilot Press, 2, Little Essex Street, W.C.2. 1s.

SEABROOK, S. P., Modern Fruit Growing. Ernest Benn, Ltd., Bouverie House, E.C.4. 7s. 6d.

SOME EFFECTS OF PRUNING "LEADERS" AND OF THE ABSENCE OF "LATERALS" ON THE RATE OF GROWTH OF STEMS OF APPLE AND PLUM.

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In the course of some work on the influence of the removal of lateral shoots upon the growth of apple trees, Hatton and Amos (1) recorded the fact that the girth at the collar of the tree was some 5 to 10 per cent. less in the absence of such laterals than when they were permitted to grow normally. The close relationship between stem girth and young shoot development has been observed previously (see 2 Bibliography) and further observations have been made with special reference to the apple (2, 3).

During 1927 and 1928 an attempt was made to obtain some further quantitative data on girth increase as related to new shoot production, in view of the importance of the matter from various horticultural viewpoints. The work of Hatton and Amos has been extended by measuring the increase in girth not merely at the end of a year's growth but also at intervals throughout the season, and by relating the measurements to new shoot growth and to pruning.

I.—APPLES.

The plants used were apple stocks of the variety Broad Leaved Paradise (No. 1) in their fourth year, which had for the purpose of the observations been grown with one straight stem for two years. These were divided into three batches of eighteen plants each, so that every batch included plants showing a similar range of vigour. From one series (A) all lateral buds were removed and throughout the 1927 season only one new stem (that from the apical bud) was allowed to develop. Series B. had no buds removed but only the apical shoot was allowed to complete its extension growth, lateral shoots being pinched back to a length of about 10 cm. Series C. were pruned so as to leave about 15 cm. of the 1926 wood intact and in this case as in A., the uppermost remaining bud was allowed to grow, lateral and adventitious buds being removed as they appeared.

At intervals throughout the season, measurements were made of the length of the terminal growths. At the same time, records were obtained of the diameter of the older stems. In 1927 each stem in Series A. and B. was measured at 3 or 4 points on the 1926 stems and those in Series C. at 1 point. All series were also measured at one point on the 1925 stems. The points at which measurements were made were marked with narrow rings of white paint and were approximately 20 cm. apart, although care was taken to avoid nodes, each point being fixed in the middle of an internode, where the cross section of the stem is nearly circular. The diameter measurements were obtained with callipers reading to 0.1 mm. and were taken in two directions and averaged.

1927 MEASUREMENTS.

New Shoot Growth.

The growth in length of the main axis is shown graphically in Fig. 1. In Series C., growth was slower early in the season but in late May was more rapid than in the other series, remaining so almost to the end of the growth period, by which time the actual length was some 55 per cent. greater than in A. and B. The two latter series reached almost identical average lengths after a full season's growth, but the graphs follow different paths, B. showing a higher rate at first and A. later. The significance of this difference in the figures is not clear.

The diameters of these 1927 shoots were measured at points 15 cm. and 30 cm. from their bases as soon as they were sufficiently lignified to allow handling without damage and the results showed small differences between Series A. and B. which proved on statistical analysis to be not significant. It is impossible to compare directly the figures of Series C. with those of A. and B., since, whilst points 15 cm. from the base of the 1927 shoots were about 35 cm. from the apex in both A. and B. such a point in Series C. was about 65 cm. from the apex owing to the greater total length of stem. Table I., however, gives a comparison of diameters as far as this is possible.

TABLE I.

Length and Diameters of 1927 Shoots after One Season's Growth.

Series.	Length.	Diameter in mm. at Different Distances from Apex.				
	cm.	15 cm.	20 cm.	30 cm.	35 cm.	45 cm.
A.	51·9	—	5·53	—	6·43	—
B.	51·7	—	5·75	—	6·14	—
C.	80·7	4·57	—	5·66	—	6·75

It would appear from this that, near the apex, the shoots of C. had a smaller diameter than those of A. and B.

If points at similar distances from the base of the 1927 wood are considered, the growth rates and final diameters are much greater in C. than in A. and B. as shown in Table II.

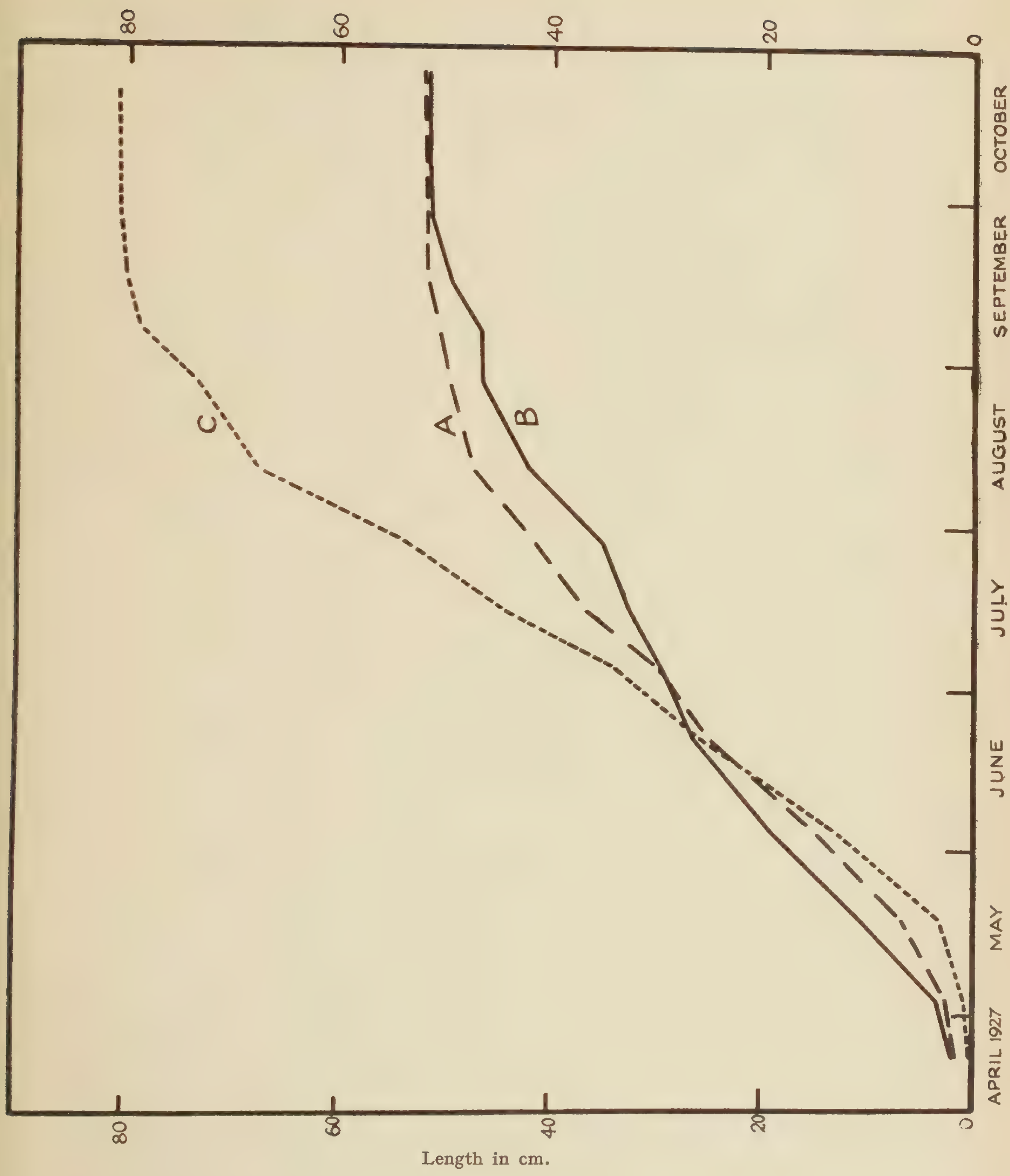

80
60
40
20
0
APRIL 1927
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
A
B
C
Length in cm.

TABLE II.

Diameter of 1927 Shoots 15 cm. from Base at Different Dates.

Series	Diameter in mm. (15 cm. from base) at Different Dates.					
	July 28.	Aug. 11.	Aug. 25.	Sept. 6.	Sept. 15.	Sept. 27.
A.	5.54	5.96	6.16	6.36	6.38	—
B.	5.09	5.48	5.74	6.04	6.10	6.11
C.	6.41	7.30	7.80	8.17	8.27	8.37

It may be noted here that over the period for which both sets of figures are available, there appears to be no very close relationship between the rate of diameter increase and the rate of shoot elongation. It is true that growth ceased in both directions at practically the same time and that the greatest diameter increase recorded occurred during a period of rapid extension growth, but apart from these points, the two curves show little agreement. The evidence however, is somewhat fragmentary and is not regarded as conclusive.

Barnett (4) found little similarity between the curves of shoot elongation and girth increase of the trunk in bearing Winesap apples. He found that in 1927, girth increase began three weeks earlier and ceased two months later than extension growth. Further, the maximum length of shoot elongation was recorded in mid-May, whilst that of girth increase occurred in mid-July.

The figures for length and diameter of new growth given in Tables I. and II. provide confirmation of the observations of Hatton and Amos (1) who found that the removal of lateral shoots whilst influencing increase in girth of the lower parts of the stem and also root development had practically no effect on the length of new growths in the " head " of the tree.

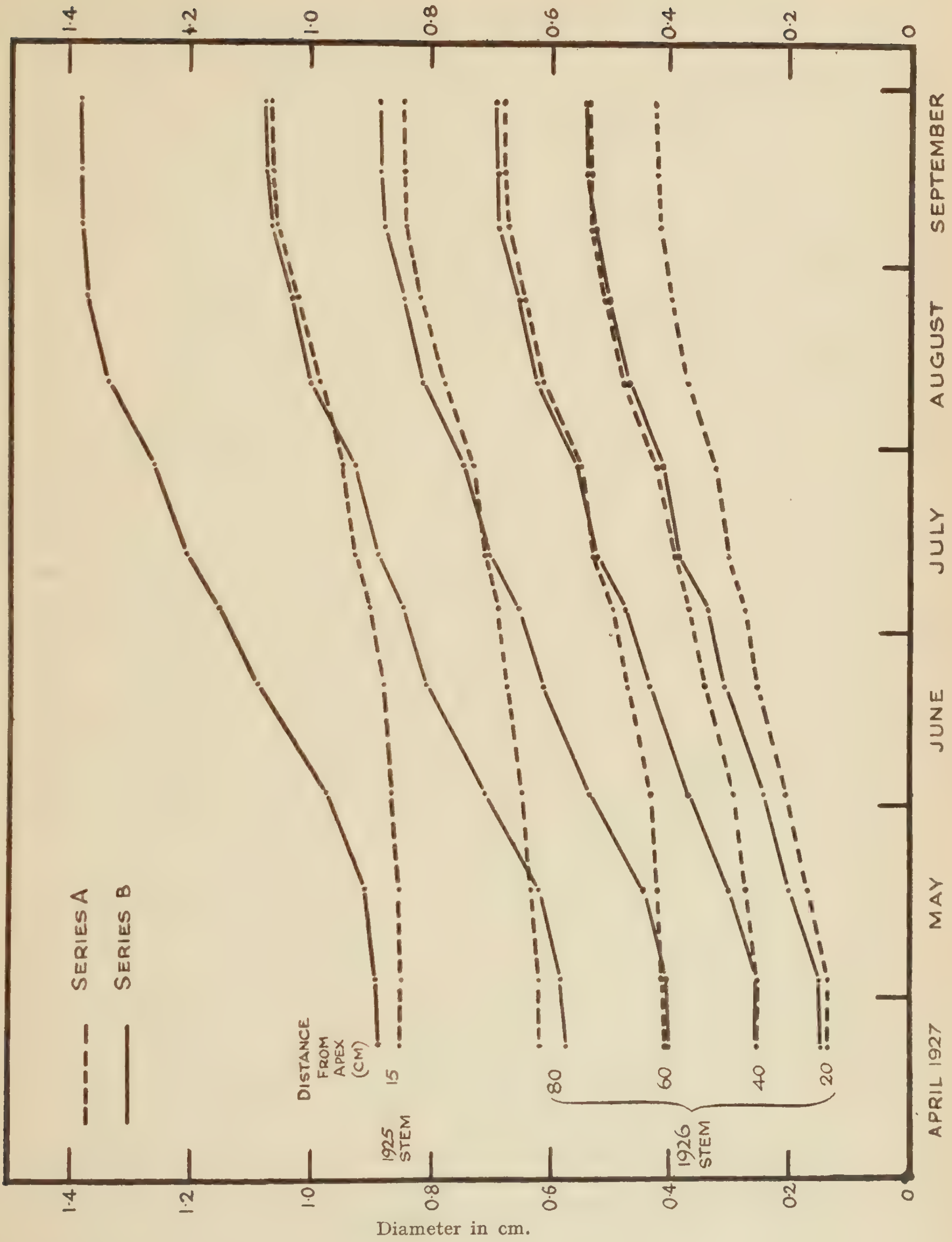
Older Stems.

The differences in behaviour of older stems in the two series A. (without laterals) and B. (with laterals) are, as might be expected from previous observations, very marked. The graphs are given in Fig. 2. which shows that whilst the diameters of the two series at corresponding points were very similar to each other at the beginning of the season, the greater amount of growth made by Series B. resulted in the diameter at any one point on those stems reaching a figure at least as large as that at a point 20 cm. lower on the stems on Series A. At corresponding points, the stems of Series B. at the end of the season were from 14 to 23 per cent. thicker than those of Series A, the increase being greater nearer to ground level.

The performance of Series C., 1925 stem (the only available point in this series which is comparable directly with A. and B.) was very similar to that of A.

FIG. 2.—DIAMETER CHANGES OF STEMS DURING THE SEASON.

Series A—Without laterals. Series B—With laterals.



At the beginning of the season Series C. was 1.6 per cent. thicker than A. but from June onwards the curves are practically coincident, corresponding average measurements differing by from 0 to 0.8 per cent.

Table III. shows the total increase made at different points on the stems of Series A. and B. after a full season's growth.

TABLE III.

Percentage Increase in Diameter of Stems of Series A. and B. after One Season.

Year's Stem.	Distance from Apex.	% Increase.		Ratio $\frac{B}{A}$
		A.	B.	
	cm.			
1926	20	54.5	72.6	1.33
1926	40	44.9	68.8	1.53
1926	60	34.1	61.4	1.80
1926	80	22.0	52.3	2.38
1925	15	17.7	41.4	2.34

In the case of B. the increase is consistently larger than in A. and this difference is generally more marked with increasing distance from the apex of the 1926 stems. In Series A., points lower on the stem were further from the new leaf-bearing shoots than were the higher points, whilst, in Series B., each point measured was in close proximity to some leafy lateral shoots, which, as well as the leaves on the main growing shoot, contributed towards the girth increase.

Some further information is obtained by considering the growth rates at different points on the stems at different periods of the season. In Series A. the daily rate of increase in the area of the cross section of the stem at a point 20 cm. below the apex of the 1926 shoot was greater in the earlier part of the season than that at a point 20 cm. lower, which in turn was greater than the increase 20 cm. lower still and so on down the stem. Later in the season, however, the rates lower down the stem became greater than those higher up and continued so until cessation of growth. These differences are not readily seen when the curves for actual diameter (Fig. 2) are considered, but are obvious when rate of increase is plotted. Fig. 3 shows the graphs of daily average rate of increase in cross sectional area of stem at the two extreme points measured, 20 cm. below the apex in 1926 growths and 15 cm. below the apex of 1925 growths. The inclusion of the curves for every point measured would have resulted in a very confused diagram and therefore only two are presented. It is worth stating, however, that the rate for the uppermost point is highest until June 3rd. It

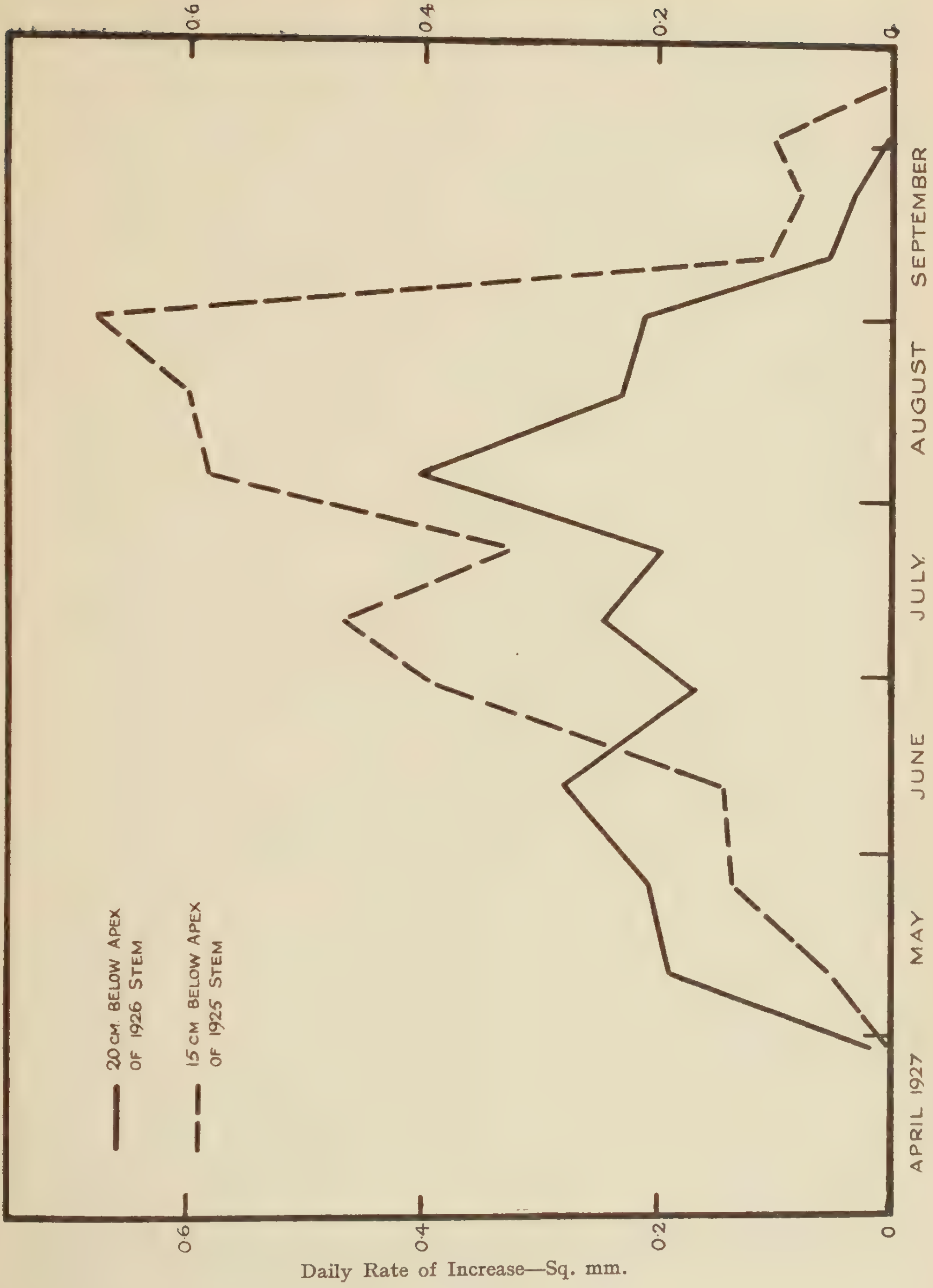


FIG. 3.—DAILY RATE OF INCREASE IN CROSS-SECTIONAL AREA OF STEMS OF SECTION A—WITHOUT LATERALS.

is exceeded by that of the point 20 cm. lower during the period June 3rd-21st and by the rates of the rest of the stem between June 21st and July 4th, after which it is continuously the lowest.

The area of the cross section has been calculated from the *average* diameter on the assumption that the stem is circular in cross section. The figures obtained thus do not differ significantly in a few examples taken at random from the averages of the cross sectional areas of individual trees.

These graphs illustrate the results of the downward spread of the commencement of cambial activity from the newly developing shoot in the earlier part of the season and of its earlier cessation in younger parts of the stem (2, 3). The high growth rate of the 1925 stem, late in the season, is remarkable and is not shown by any other portion of the stems in any series.

The growth rates of Series B. (the two extreme examples of which are given in Fig. 4) present a picture differing considerably from that in Series A. The rates at corresponding points were greater throughout the season in the trees of Series B.—which retained their laterals, than in those of Series A. and, further, the uppermost part of the 1926 stem, in contrast with that in Series A., grew *less* rapidly practically from the beginning of the season, than points lower on the stem. Growth ceased at all points at the same period, within the limits set by the lengths of the time intervals between successive measurements. It should be noted that this is not contradictory to the findings of Swarbrick (3) who observed that the cessation of cambial activity occurred first in the younger stems and later in older ones. In the present case all points measured, except one, were on stems of the previous season and the exception was close to the apex of two year wood. All these points, in Series B., were in close proximity to newly developing shoots, whereas Swarbrick considered stems up to five years' old. Further, small differences in the time of cessation of growth could not be detected in the present work, where the shortest interval between readings was nine days.

Figs. 3 and 4 show clearly the process giving rise to the differences at the end of the season between the girths of stems carrying normal lateral shoots and of those from which laterals have been removed. In the former case, each point on the stem is in close proximity to some new leaf-bearing shoots and consequently the cambium at that point becomes active early in the season under the influence of adjacent new growths. In the latter case, lateral buds having been removed, points lower on the old stem are further from the region of new shoot formation with the result that cambial activity is less rapid at first than at points higher up, i.e., nearer new leaf-bearing shoots.

The higher rate observed at the end of the season in the case of the lower points may be associated with the difference in circumference of the cambial layer. One complete ring of new elements developed on the lower portions

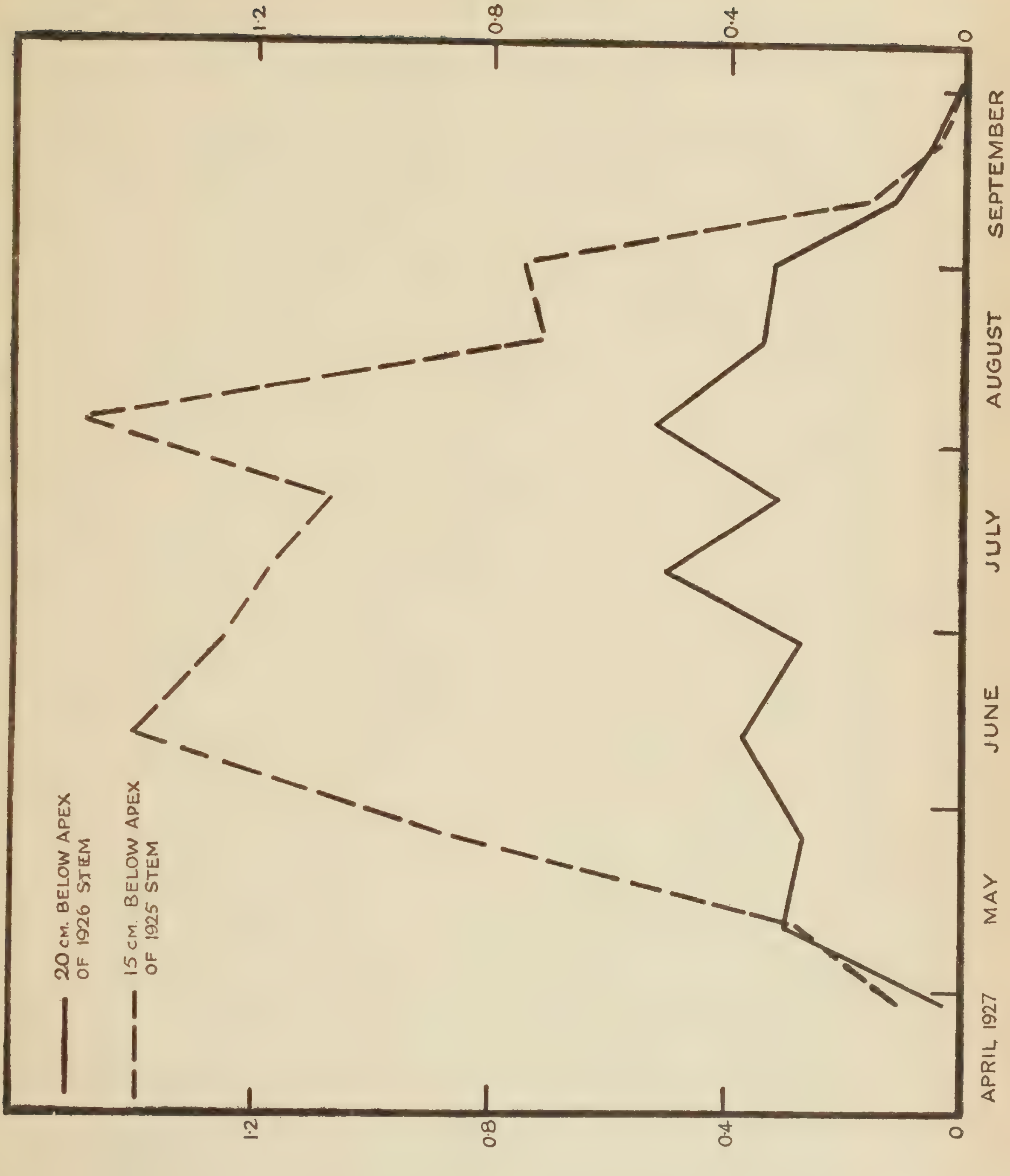


FIG. 4.—DAILY RATE OF INCREASE IN CROSS-SECTIONAL AREA OF STEMS OF SERIES B—WITH LATERALS.

of the stem would result in a greater increase in cross-sectional area than would one ring in the upper region, but measurements are not available for the calculation of the rate of increase of cross section in relation to circumference of the cambium.

Apart from the influence of adjacent leafy shoots in inducing cambial activity early in the season in Series B., the generally higher growth rates shown by these trees and their greater diameter at the end of the season, as compared with Series A., is, of course, to be associated with the much greater area of leaves which they carried.

In the case of the leader pruned trees (Series C.) the 1925 stems behaved very similarly to the 1925 stems in Series A. Their rate of growth was lower in the earlier part of the season than that of the 1926 stems, but later in the year the older stems exceeded the younger. This is interesting because in Series C., the point 15 cm. below the apex of the 1925 stem was approximately the same distance from leafy shoots as the corresponding point in Series B. and much nearer than in Series A. In Series C., however, the leafy shoots in question were rapidly growing leaders whilst in Series B. they were short laterals, ceasing extension growth early in the season. The fact that C. behaved like A. and not like B. suggests that the nature of the associated young shoots as well as their proximity is significant in this connection.

1928 MEASUREMENTS.

The trees were kept under observation throughout the 1928 season but some modifications were made in the pruning treatments. The single shoots which were produced during 1927 on Series C. were not pruned in winter but lateral buds were removed and only the terminal bud was allowed to develop. Thus Series C. was treated in 1928 exactly as Series A. had been treated in 1927, the trees having a single stem and no laterals on the previous year's growth. The diameter of the previous year's stem was measured at four points, as in Series A. in 1927, and the growth of the former in 1928 proved to be exactly comparable to that of the latter in 1927. The growth rate 15 cm. below the apex of the 1927 stem was highest until the beginning of June and it was surpassed successively by that of points 15, 30 and 45 cm. lower between that date and July. Thereafter, the lower portions of the stem grew more rapidly until the end of the season.

During season 1928 Series B. was again left unpruned, except that the laterals, as in 1927 were pinched at about 10 c.m. only the apical shoot being allowed to develop unchecked. The trees thus carried numerous laterals on both 1926 and 1927 stems. Series A. was treated during 1928 in exactly the same way as Series B., and so each tree consisted of a newly developing 1928 shoot, 1927 stem with short laterals and 1926 stem with occasional small laterals arising from adventitious buds. Thus, the points on the 1927 stems were similarly situated in both Series A. and B. in relation to the number of leafy shoots above them, but points on the 1926 stems of Series B. were more favourably situated than those of Series A. in this respect.

This difference was reflected in their respective performances. As in 1927 (see Table III.) the increase in diameter of the 1926 stems at the end of the season was considerably less in Series A. than in Series B. The difference between the total growth of 1927 stems—which in both series carried leafy laterals—was far less, though still in favour of Series B. The curves of growth rates of the 1926 stems showed the same relationship as in the 1927 measurements (Figs. 3 and 4). In Series A., points low on the stem showed the lower rates until June, after which the position was reversed. In Series B. the lower portions of the stem grew more rapidly practically throughout the season, the difference between the " feathered " and " defeathered " stems being quite similar to that shown in 1927.

The curves for corresponding points on the 1927 stems, which in both series carried laterals, were almost coincident until June, after which Series A. fell slightly behind.

Thus, the figures obtained in 1928 were fully confirmatory of those recorded in the previous season, and the results are complementary to those already recorded.

In the absence of lateral leafy shoots, cambial activity in the lower portions of the stem starts late and the growth rate is relatively slow early in the season, with the result that the total increase in size is less than in stems which carry the normal complement of side shoots, and which show high growth rates in May and June even towards their lower ends.

II.—PLUMS.

During 1928 some measurements were also made of diameter increase of the stems of plums. Two series of plants were used, some two-year old " Laxton's Delicious " which were being prepared in the nursery to make standard trees, and some nine-year old half-standards of the variety " Pershore " and " Myrobolan." The Laxton's Delicious carried leafy laterals over the whole length of their main stems and might be compared with Series B. of the Apple stocks already considered. They were measured at three points, approximately 30, 90 and 150 cm. from the ground level. The Pershores and Myrobolans had trunks about 140 cm. long, carrying, of course, no laterals and these trunks were measured at 45 cm. and 110 cm. from ground level.

Increase in diameter in the " feathered " stems of the Laxton's Delicious began early in April and there was no appreciable difference in the date at which growth began at different levels. At the time when the first increase was detected, the buds had burst and had developed leaves up to 2 cm. long. Three weeks previously the buds had already opened and had extended to a length of 1 cm. or so, but no stem expansion had been detected at this stage. The daily rate of increase in cross sectional area of the stem was slightly greater at the lower point than at higher points until early June, after which the rate in the uppermost region decreased. At the lower points, however, a further increase in rate was measured during June, the maxima here being later than at the point 150 cm. from the ground level. In their main features, the curves closely resemble those obtained from Series B. of the apples, thickening beginning almost simultaneously throughout the two year old stem which was fully furnished with laterals.

In the Myrobolans, diameter increase of the bare trunks also began early in April, by which time the buds had developed into new shoots up to 5 cm. long. At the same time, the new shoots of Pershore were 2 cm. long and the trunks showed a very slight increase in girth.

Until towards the end of May both varieties showed a more rapid rate of increase in the upper regions than in the lower, but thereafter, the position was reversed, as in Series A. of the apples, and the lower portion of the stem grew faster.

Insofar, therefore, as these plants are comparable with the apple stocks already considered, they have provided confirmation of the results obtained with the latter.

Acknowledgment is due to Miss I. D. Skinner and to the Recording Staff of the Station who have assisted in obtaining the large mass of records used in the preparation of this paper.

SUMMARY.

The absence of lateral shoots on older stems had practically no influence on the rates of extension growth or of diameter increase of newly developing shoots.

Stems carrying no laterals show lower rates of diameter increase throughout the season than normally furnished stems. The lower region of the former grows more slowly than the upper region in the early part of the season, but later the position is reversed. In the " feathered " stems, the lower region grows as rapidly as the upper at first and much faster thereafter.

Measurements of plum trees have given results of a similar nature.

Although the new shoots of leader-pruned apples behave quite differently from those of unpruned trees, the increase in diameter of older stems of the former follows a course resembling that of older stems of " defeathered " trees.

The results provide some indication of the manner in which the previously recorded differences between furnished and unfurnished stems after a season's growth are arrived at, and show how the differences in the progress of the downward "wave" of cambial activity from newly developing shoots are reflected in the girth of older stems.

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SOME RESULTS OF EXPERIMENTS IN BREEDING BLACK CURRANTS.

PART I.—THE SELF POLLINATED FAMILIES.

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Introductory.

Whilst much work has been done in the past by fruit raisers on the breeding of black currants, the details of the work have rarely been made generally available owing to the fact that the object of the crosses has been essentially the production of new varieties of commercial value. Success in this direction has been signalised by the distribution of the material produced, but no information has been procurable detailing either successes or failures, which might provide indications of the genetics of the species or of possible avenues of future research.

Once a satisfactory method of classification of black currant varieties on botanical characters had been formulated (1, 2) it became possible to attack systematically the problem of the combination in a single variety of good qualities borne separately by several varieties. At the same time it became important to study the genetical relationships of the groups and varieties into which the species had been divided.

In most essential respects the black currant is a fairly easy subject with which to deal, particularly when the technical details have been mastered. The flowers, though small, are not difficult to manipulate and pollen is usually plentiful on healthy, unreverted bushes.

Method.

All the seedlings dealt with in this paper were raised from bushes growing in the open plantations. All the usual precautions against contamination by foreign pollen were, however, taken. The seed was collected as soon as the fruits were ripe, and sown, when possible, immediately after gathering, in shallow wooden boxes. The soil was steam sterilised before use. Black currant seedlings, in their young stages are gross feeders and will make a large amount of growth in a short time under suitable conditions.

System of Recording.

Whilst, in the search for new varieties of commercial value, attention was directed towards such characters as growth, cropping and fruit quality, it was necessary for the genetical enquiry to study, in addition, many characters of minor commercial importance. In fact, particular emphasis has been laid upon those characters which differed most markedly from variety to variety or group to group, and, since it was hoped to obtain as comprehensive a picture as possible of the constitution of each individual within a family, a large range of characters were studied. These characters were studied, season by season, for a number of years upon the same material.

THE MATERIAL.

The material studied has been bred from individuals of commercial varieties which have been under observation for some years at this Station. The notes given below on the seedling families are preceded in each case by a brief description of the parent variety for the purpose of reference or comparison. More detailed descriptions can be obtained in earlier papers (1, 2, 4, 5). Hatton found that all the varieties with which he had to deal fell readily into four well defined groups, the French, Boskoop, Goliath and Baldwin types, which he later increased to five to include a number of varieties of Canadian origin.

The conditions under which these seedlings were growing were somewhat unsatisfactory. While the soil was moderately good, the situation was very exposed on all sides to the severe conditions frequently experienced during the blossoming period. For this reason, the cropping performance of these seedlings was always very poor and while they gave sufficient fruit to make possible estimates of fruit size, flavour, etc., little data on their fruiting capabilities were obtainable.

By the expression " self-pollinated " family or merely " selfs " is meant populations of seedlings which have been obtained from seeds the result of applying their own pollen to the flowers of a single bush. When such seedlings themselves produce flowers, the stigmas of which are again fertilised with their own pollen, the resulting seedlings are spoken of as " second generation selfs."

1. SEEDLINGS OF FRENCH BLACK. SELFED.

Parent Variety : French Black (Merveille de la Gironde).

Characters : Large, compact bush, much branched ; *buds during winter* of medium size, *conical and pointed, pink to purple in colour, very tightly arranged ; late in coming into leaf in the Spring ;* one to three flower racemes per node, *of medium length ;* leaves medium to large, lobes regular and acute, leaf sinus very shallow, often flat ; *fruit medium to small, very acid, mid season, very subject to " running off."* (3).

First Generation.

One hundred and sixty-one seedlings comprising three families of this variety were studied.

1. *Leaf Characters.* The most outstanding difference among seedlings of French Black was in the shape of the leaves but there were also certain corresponding modifications in other characters. The plants fell naturally into two groups, easily distinguishable by leaf characters. The majority of the seedlings were of a type (termed Type A., see Plate 1), which resembled the parent very closely in the general shape of the leaves, having the flat leaf sinus and characteristic leaf marginal serrations of the parent.

The remainder of the family (Type B., see Plate 3), approximately a quarter of the whole, produced leaves which were more attenuated and pointed than those of the parent. The serrations were markedly more acute and were invariably innervated. The extremity of the terminal lobe was frequently surmounted by a filamentous extension of the mid rib which continued for about a quarter of an inch above the margin of the lamina and was terminated by a tiny piece of green leaf tissue (see Plate 8). In other cases the apex of the terminal lobe was extremely foreshortened and bi- or trifid. The veins were noticeably more prominent and flattened on their under surface than those from leaves from normal bushes and the junctions of the side veins and the mid rib were, in some cases, thickened and much emphasised. While the number and distribution of the veins was normal, the angles between the chief veins of the lateral lobes and the mid rib were considerably diminished giving to the leaves a narrow and elongated appearance.

2. *Vigour.* It is necessary to realise that this character is not only the expression of inherent qualities but that it is also considerably influenced by external factors. The incidence of conditions of the seedbox, of light, air and nutrition and of disease may be of prime importance.

Observations extending over seven years have shown that these seedlings were by no means uniformly vigorous, although there was no apparent difference between bushes of the two leaf types A. and B. Thus, at five and six years old, a proportion of these seedlings, varying from five to ten per cent. were described as definitely dwarf and from 20 to 50 per cent. as intermediate.

3. *Bud Colour.* This character seems to have been transmitted from the parent variety to the seedlings with very little modification. Observations during the winters of four years failed to detect a single seedling whose buds could be described as green, although in each year a proportion were described as intermediate in colour. There was no apparent difference in bud colour between the two types of seedlings, A. and B.

The figures showed that there was a considerable tendency for the bud colour to fluctuate somewhat from season to season; this has been repeatedly noticed among bushes of varieties growing in the plantations and may represent the response of the bushes to slightly differing climatic conditions.

4. *Form of the Buds.* Data collected during three winters upon 148 individuals showed that the seedlings had buds either conical or intermediate in shape with compactly or intermediately wrapped bud scales. In most seasons the seedlings resembled their parents very closely in regard to these characters.

5. *Season of Coming into Leaf.* These seedlings were among the latest to burst into leaf in the Spring, showing a considerable degree of uniformity in this respect.

6. *Fruit.* (*a*) *Raceme Length.* This character is of prime importance in the black currant and one of which the breeder of new varieties is bound to take cognisance, since upon it depends the ease and celerity with which the fruits can be picked. Observations of this character upon 160 seedlings during four years indicated that the racemes of the seedlings were, in the majority of cases, of intermediate length. In the case of one family, a somewhat large percentage, approximately half the total population, were described as short in the seedling's fifth and sixth years while a small proportion, varying from two to five per cent., have in each year been described as long.

Actual measurements of the lengths of the racemes of both the parent variety and the seedlings indicated that the racemes of the latter were not any longer than, at a comparable age, were those of the former. These remarks refer to the whole of the seedlings and it was observed that the racemes of Type B. seedlings were, if anything, a trifle longer than those of the A. type. Similarly, the racemes of the B. type were held more stiffly, being posed almost horizontally.

(*b*) *Quality.* The fruits of the seedlings were invariably either medium or small in size. The flavour, whenever it was estimated, was acid and astringent, especially in the B. type, or as an exception, sub-acid. They were mid-season or, more rarely, late mid-season, in time of ripening.

7. *Cropping.* The crops borne by these seedlings have rarely justified the expenditure of time and labour in picking, the bushes, in many cases, being almost completely devoid of fruit. This appeared to be due, not so much to a deficiency of flowers, as to the failure of the flowers to set fruits, attributable to " running off " or failure of pollination. Thus, in 1927 and again in 1928, no bush set more than 50 per cent. of the total quantity of flowers borne while approximately 80 per cent. of the seedlings set 10 per cent. or less of their flowers. In the few years in which the actual weight of fruit borne by the seedlings has been recorded, the average per bush was extremely small.

8. *Big Bud.* There was no unusual infestation of Big Bud upon the plot on which the seedlings were growing. In 1926, Big Buds were observed on two seedlings both of the parental leaf type (A.), one having buds round in shape with ragged scales and the other with conical shaped buds and compact scales.

In the spring of 1927, Big Buds were noted upon a single bush of the A. type, with round-shaped buds and intermediately wrapped bud scales. No Big Buds have been recorded in any year upon bushes of the B. leaf type. (Except where otherwise noted, it is to be understood that no Big Buds have been recorded upon the seedlings.)

Second Generation.

(*a*) *The Normal Type* (*A.*) *selfed.* This type, on the single occasion upon which it has been selfed and the family studied, produced eighteen individuals, of which seventeen were similar to the parental French leaf type (A.) and only one reproduced the abnormality in regard to leaf dentation and shape, (Type B.) Little can be said of these seedlings, as they have been somewhat backward and have never borne any fruit. The buds of the majority of the seedlings were red in colour and of a conical or intermediate shape. The bud scales were either compactly or intermediately wrapped.

It appeared from the composition of this second generation that the A. type was identical in all major respects with the French parent.

(*b*) *The Abnormal Type* (*B.*) *selfed.* A single family was raised from the selfing of a seedling of the abnormal leaf type which has been described above, and of the seventeen individuals which resulted, all reproduced the abnormal type which therefore appears likely to be homozygous for these leaf characters. They possessed little economic merit under our conditions, failing to set any appreciable quantity of fruit although a moderate number of flowers were produced. The seedlings were of average vigour, and, when examined during the dormant season, the buds were somewhat more red in colour and conical in shape than those of seedlings of corresponding leaf type in the first generation. At the same time, the bud scales were arranged somewhat more loosely.

While individuals of this second generation (Type B. selfed), were very similar in leaf characters to the Type B. plants of the first generation, the racemes appeared to be somewhat longer.

It is proposed to repeat many of these selfings during the next few years under more rigidly controlled conditions. In the light of the knowledge already gained, it should be possible also, to make a considerable advance in the direction of greater precision in the recording of many of the characters of the seedlings. Experience has emphasised the advantages to be derived from continuing the observations from season to season since many of the characters which have been studied do not appear to remain constant.

II.—SEEDLINGS OF SEABROOK'S BLACK—SELFED.

Parent Variety: Seabrook's Black.

Characters: Similar to French Black. Hatton (1) says of it: " In vegetative characters it is extremely difficult to distinguish from Merveille de la

Gironde. Both wood and buds often appear somewhat darker in colour and the bunches more crowded."

First Generation.

Approximately 200 seedlings comprising two families were studied.

1. *Leaf Characters.* When Seabrook's Black was selfed the offspring which resulted differed markedly among themselves. These differences although they were most readily seen in the shape of the leaves, extended also to other characters. Upon broad distinctions of leaf shape, the population could be divided into four fairly well marked classes. Of the largest of these four classes, for convenience designated Type SR. (see Plate 2), it is sufficient to say that, like the corresponding type in French Black (Type A.), it resembled the parent very closely. About one-ninth of the members of this class, however, possessed a somewhat deeper leaf sinus and bore a fleeting resemblance to the variety Baldwin on general leaf characters. The remaining type of bush to which Seabrook's Black gave rise in common with French Black (Type B.), was morphologically the same in both varieties, although in certain cases the peculiarities of leaf structure described for the variety French Black, were less pronounced in the case of Seabrook's Black, some of the seedlings of this type (called for convenience, Type S., see Plate 3), being only slightly different from the normal type of leaf.

Of the two types of seedlings found in populations from Seabrook's Black but not in those from French Black, the predominant type, called Type R. (see Plates 4 and 9), had leaves almost rounded in appearance, the terminal and lateral lobes being much suppressed. In some cases, the terminal lobe was absent altogether, the two lateral lobes coalescing, leaving a sinus like indentation at the top of the leaf. Considerable variation in leaf form was found to exist among leaves upon the same bush, almost every gradation from leaves having well defined though much blunted terminal and lateral lobes, to leaves which were reduced to an ovate or reniform shape with few serrations being present. The serrations of the leaf margin were, in every case, much blunted and at times absent altogether. In many cases no apparent mid rib persisted through the entire length of the leaf; the rib, after passing up from the petiole into the lamina, ramified in an inconsequent manner, having no resemblance to the normal venation of a black currant leaf. Bushes of this type were characterised by a profuse stipulary growth and the coloration of the leaves was frequently lighter than on bushes of the parental type.

The fourth type observed, Type r (see Plates 5 and 9), resembled in its broad particulars that described above (Type R). The leaves were dark green in colour and in shape bore no resemblance to the ordinary black currant leaf. In their extremest form the leaves were almost round in shape and were adherent along their lower margins for a short distance round the petiole, giving the whole leaf the semblance of a trumpet or hollow cone. The leaf petioles were longer and more slender than in the other types. The veining of the leaves was extremely irregular, a main vein frequently dividing and then reuniting further up the leaf, leaving, as it were, an island of leaf tissue, completely surrounded by the converging vein. The veins frequently gave rise to curious pointed outgrowths, apparently of a vascular nature, upon the undersides of the leaves and at various distances along the length of the veins.

The numerical proportions in which the bushes of the four types of leaf form appeared are given in Table I. As may be seen, the total populations are somewhat small and much significance cannot be attached to the figures until larger families have been raised and studied. Nevertheless, they show moderate agreement with theoretical expectation based on Mendelian two factor segregation.

TABLE I.

Distribution of Leaf Types in Seabrook's Black selfed.

Family.	Number of Bushes.	SR Leaf Type.	S Leaf Type.	R Leaf Type.	r Leaf Type.
I	95	54	18	23	
2	102	65	17	17	3
Totals	197	119	35	43	
Theoretical Expectation. 9 : 3 : 4 ratio :		111	37	49	

Although these abnormal leaf forms have invariably occurred whenever Seabrook's Black has been selfed, they have never been found among the offspring of crosses of which Seabrook's Black has been one of the parents, thus suggesting the recessive nature of the factors concerned.

2. *Vigour.* Considerable differences in vigour were found to exist among these seedlings. While bushes of the SR. Type and of the S. Type were, upon the average, almost as vigorous as the parent, seedlings of the R. type were somewhat less vigorous with more whippy and slender growth, while bushes of the r type were, in many cases, definitely dwarfs with stunted and extremely slender growths.

Observations during six years upon 200 bushes have shown that very few of these seedlings remained definitely dwarfs throughout their life. Thus, while at five years old about fifteen per cent. of the bushes were described as dwarf, at eight and nine years old only about one per cent. were placed in this class, while almost ninety per cent. of the bushes were classed as vigorous.

3. *Bud Colour.* Four years' observations indicated that there was a considerable degree of fluctuation in intensity of bud colouration from season to season. In most years, a small proportion of the bushes had buds described as green, while a large proportion were placed in the intermediate class. The figures seemed to indicate that seedlings of the S. type had buds which were a little more reddish than those of the SR. type while those of the R. and r types seemed to be slightly less intensely pigmented.

4. *Form of the Buds.* Four years' observations have shown that the majority of the bushes had buds either conical or intermediate in shape with compactly or intermediately wrapped scales. A small percentage of the bushes had buds rounded in shape in each year while a rather larger proportion had ragged bud scales. Little discernable difference was found between bushes of the four leaf types with reference to these characters although there were indications that bushes of the S. type had buds somewhat more conical in shape than the average and, in certain years, at least, the bud scales were not so closely arranged as in those of the SR. type.

5. *Season of Coming into Leaf.* These seedlings were invariably among the latest to burst into leaf in the Spring.

6. *Fruit.* (*a*) *Raceme Length.* A considerable series of observations upon this character have shown that, in the majority of cases, the racemes were either of intermediate length or short. A very small proportion, in no case greater than seven per cent., were recorded as having long racemes during their earlier years. Actual measurements of raceme length made upon one family of seedlings, five years of age, illustrated the difference to be observed between bushes of the various leaf types. Ten racemes from each of ninety-four bushes were taken at random and measured. These data are summarised in Table II.

TABLE II.

Raceme Lengths of Seedlings of Seabrook's Black Selfed.

Leaf Type.	Number of Seedlings.	Average Length of Raceme.	Longest.	Shortest.
SR.	63	39.0 mm.	53 mm.	25 mm.
S.	16	40.5 mm.	57 mm.	28.5 mm.
R. r.	15	34.0 mm.	43 mm.	22 mm.

These figures indicate that while the racemes of the S. type appear to have been slightly longer, on the average, than those of the SR. type, those of the R. and r types, taken together, were considerably shorter. Measurements of the raceme length of bushes of the parent variety show that they average from 40 to 55 millimeters per bush. It will thus be seen that the racemes of these seedlings were considerably shorter, upon the average, than those of the parent.

(*b*) *Quality*. The fruits were either medium in size or small. Owing to the large numbers involved, it was not possible to make very frequent estimates of the flavour of the fruits, but in the two years during which the flavour was judged it was found to be either acid or sub-acid. The fruits of a greater number of bushes of the S. leaf type were acid than of the SR. type. The seedlings were uniformly either mid-season or late mid-season in period of ripening.

7. *Cropping*. Observations during two years showed that the seedlings were very prone to "running off." Estimates of the proportion of the flowers which set fruits showed that fewer than three per cent. of the seedlings set more than 30 per cent. of the blossoms which they bore in either of the two years 1927-28, while about 65 per cent. set 1 per cent. or less. The fruits, whenever they were thought worth the trouble of weighing, were almost negligible in quantity and, although occasionally comparatively high cropping bushes were found, they did not bear serious comparison with bushes of the parent variety of similar age but more advantageously situated.

8. *Big Bud*. In 1925, eleven Big Buds were observed and removed from six bushes all of which were of the SR. leaf type except one which was of the R. type. In 1926 three bushes were infested, the R. type individual which had had the trouble in the previous year and two bushes of the SR. type neither of which had previously been infested. All the bushes had compactly wrapped bud scales with the exception of one which had intermediately wrapped scales.

In this connection, the writer is indebted to Mr. A. M. Massee of the Entomological Department at this Station, for the following details of experiments which he made during the years 1924-27. Mr. Massee took healthy, potted plants, apparently free from mites, of seedlings of the first generation, SR., S., R. and r leaf types from Seabrook's Black selfed, and also plants of the variety itself as controls. Direct inoculations with the Big Bud Mite were made during the winter and spring of 1923 and continued each season until the Spring of 1927. In the autumn of 1927 the buds of each bush were examined to determine whether mites were present in the apparently healthy buds.

Of eighteen plants so treated, Massee found only seven which did not show enlarged buds at examinations made during the winters of 1924, 5 and 6. Of these, two were seedlings of the SR. leaf type, one was a seedling of the S. leaf type, two were seedlings of the R. leaf type, while the remaining two were bushes of the parent variety. Finally, at his examination in 1927, of apparently normal buds, Massee found only five bushes without mites in the buds. Of these, only one, a control bush of the parent variety, had not had Big Buds recorded upon it during the preceding examinations. Massee concludes as the result of his study: "It will be seen that none of the seedlings was entirely free from mites with the exception of one of the Seabrook's control plants (and a few mites were found on this bush during the winter of 1928), but that some seedlings, namely, the R. type, one S. type seedling, and the controls were undoubtedly resistant to mite attack."

Second Generation.

(*a*) *The Normal* (*SR.*) *Leaf Type selfed.* Altogether 266 seedlings comprising four families were studied.

1. *Leaf Characters.* When the SR. leaf type seedlings derived from selfing Seabrook's Black were themselves selfed they gave rise to families composed of individuals of the four leaf types, SR., S., R., and r, in proportions which are shown in Table III.

TABLE III.

Distribution of Leaf Types, Second Generation, Seabrook's Black (*SR. Leaf Type*) *selfed.*

Family.	Number of Seedlings.	SR Leaf Type.	S Leaf Type.	R Leaf Type. r Leaf Type.
1	7	3	2	2
2	77	53	9	15
3	52	31	10	11
4	130	77	27	26
Totals:	266	164	48	54
Theoretical Expn. 9 : 3 : 4 ratio:		149	50	66

So far as our observations have extended, there seems to be no perceptible difference between these types of leaves or bushes as they appear in the second generation when compared with the corresponding types in the first.

2. *Vigour.* These seedlings were moderately vigorous during the period in which they were under observation. While, at two years' old, about 5 per cent. of them were recorded as dwarfs, this proportion tended rapidly to diminish as the seedlings grew older, until, at four years old, fewer than 2 per cent. of them were dwarfs and more than 75 per cent. definitely vigorous. There appeared to be no very marked differences in the vigour of seedlings of the four leaf types.

3 and 4. *Bud Colour and Form.* The buds of the seedlings were largely red or intermediate in colour. The buds were intermediate or conical in shape with either compactly or intermediately wrapped bud scales.

5. *Season of Coming into Leaf.* The seedlings were invariably either late or late mid-season in time of bursting into leaf in the Spring.

6. *Fruit.* (*a*) *Raceme Length.* The racemes were usually of medium length. With reference to differences in length between the racemes of seedlings of the four leaf types, Table IV. summarises the results of measurements made upon a single family, in its fifth year, ten racemes from each of seventy-four bushes being taken.

TABLE IV.

Raceme Length, Second Generation, Seabrook's Black selfed.

Leaf Type.	Number of Seedlings.	Average Length of Racemes.	Longest.	Shortest.
SR	53	38.6 mm.	52 mm.	21 mm.
S	7	36.8 mm.	45 mm.	27 mm.
R	12	33.7 mm.	52.5 mm.	19 mm.
r	2	30.5 mm.	35 mm.	26 mm.

While the racemes of the S. type bushes were, in this instance, actually shorter than those of the SR. type, bushes of the R. and r. types still have racemes considerably shorter than those of the other two types.

(*b*) *Quality.* The fruits of these seedlings were in every case of medium size.

7. *Cropping.* The cropping performance of these seedlings was extremely poor. In no case did any seedling set more than 30 per cent. of the flowers which it bore while not less than 80 per cent. of the bushes set 1 per cent. or less of their blossoms.

(*b*) *The Abnormal Leaf Type* (*S.*) *selfed.* 194 seedlings, comprising four families were studied.

1. *Leaf Characters.* When bushes of the S. leaf type derived from Seabrook's Black selfed, were selfed, they gave rise to families consisting of individuals of the three leaf types: S., R., and r. The numerical proportions in each family was somewhat variable owing to the small numbers involved. The figures are given in Table V.

TABLE V.

Distribution of Leaf Types, Second Generation, Seabrook's Black (S. Leaf type) selfed.

Family.	Number of Seedlings.	S Leaf Type.	R Leaf Type.	r Leaf Type.
1	17	16	1	
2	33	26	7	
3	12	10	2	
4	102	80	22	
5	30	23	7	
Totals:	194	155	39	
Theoretical Expectation 3 : 1 ratio:		146	48	

2. *Vigour.* Observations indicated that the seedlings were somewhat variable in vigour. About 10 per cent. of the bushes were definitely dwarfs in their fourth year. Bushes of the R. and r. leaf types appeared to be somewhat more dwarf than those of the S. type.

3 and 4. *Bud Colour and Form.* The buds were largely reddish in colour, intermediate to conical in shape with compactly wrapped bud scales.

5. *Season of Coming into Leaf.* All these seedlings were late in time of bursting into leaf in the Spring.

6. *Fruit.* (*a*) *Raceme Length.* Very few of the seedlings bore any fruit in the years over which the observations extended. Where measurements were obtainable the racemes were found to be of medium length.

(*b*) *Quality.* The berries were either medium or small in size. The flavour, where it was estimated was found to be either acid or sub-acid.

7. *Cropping.* Observations of the proportions of the blossoms which matured fruits showed that in the case of no bush did more than one per cent. of the blossom set. The crops borne by these seedlings were negligible in quantity.

(*c*) *The Abnormal Leaf Types* (*R. and r.*) *selfed.* Approximately 200 seedlings comprising five families were studied.

1. *Leaf Characters.* It has not been possible in many of these families to distinguish between members of the two genotypes R. and r. While it has been practicable, in certain cases, to discriminate bushes with an extreme type of leaf abnormality or exceptionally stunted growth, in general, the bushes of the

two types showed a degree of variability in leaf form which made an accurate separation of R. and r. type individuals an extremely difficult matter. The most that can be said at the moment, therefore, is, that when we have selfed seedlings of the R. and r leaf types, obtained from families of Seabrook's Black selfed, the families which resulted were themselves composed exclusively of seedlings of the R. and r. leaf types. So far as our observations have extended, the leaf forms produced in these second generation families were in every respect similar to those which occurred among the seedlings of the first generation.

2. *Vigour.* Observations showed that these seedlings were somewhat variable in vigour. At three years old, one family consisting of sixty-five bushes, ranged in height from 60 to 10 centimeters, and of these, 25 per cent. were below twenty centimeters in height and 25 per cent. were above forty centimeters.

3 and 4. *Bud Colour and Form.* The majority of these seedlings had buds which were red in colour, intermediate or conical in shape with compactly wrapped bud scales.

5. *Season of Coming into Leaf.* They were invariably among the latest to burst into leaf in the Spring.

6. *Fruit.* (*a*) *Raceme Length.* Very few of these seedlings bore any fruit during the years over which these observations extended. Where observation was possible, the racemes were found to be of medium length or short.

(*b*) *Quality.* The few seedlings of these families which cropped bore fruits of medium size and acid flavour. They were mid season in time of ripening.

7. *Cropping.* In 1927, of five seedlings which produced blossom, two set no fruits at all and three set approximately 10 per cent. of the flowers borne. Crop weights, obtained in a single year showed that the aggregate quantities of fruit borne were negligible.

Briefly to recapitulate, Seabrook's Black when it was selfed, gave rise to seedlings of the four leaf forms, SR., S., R. and r. When bushes of the SR. leaf type were selfed they produced populations composed of seedlings of the four types of leaf shape SR., S., R. and r. When bushes of the S. leaf type were selfed the families which resulted consisted of individuals of the three leaf forms S., R. and r. Finally, R. and r. leaf type bushes, when selfed, were found to breed true and produced seedlings of the R. and r. leaf types only.

When once seedlings of French Black and Seabrook's Black had been raised and the fundamental difference in their segregation for leaf form observed, it became of considerable interest to follow out with some care the behaviour of selfed families of varieties the similarity of whose vegetative characters to those of French and Seabrook's, suggested a common origin. Of these varieties, Siberian seemed the most promising with which to commence, as it was reported to have originated as a wild variety and, therefore, probably to be of great age.

III.—SEEDLINGS OF SIBERIAN—SELFED.

Parent Variety. Siberian.

Characters: Similar to French Black. Hatton (1) describes it as: "Similar in all winter characteristics to French Black or Merveille de la Gironde." Bunyard (4) states that it was found in a wild state in the Altai Mountains, and continues: "It is therefore interesting as a wild variety of good sized fruits obtained without the supposedly ameliorating effect of cultivation."

First Generation.

A single family consisting of seventy-eight seedlings was studied.

1. *Leaf Characters.* When Siberian was selfed, the seedlings which resulted were of the four leaf types, SR., S., R. and r., already fully described for the variety Seabrook's Black. Although the family was somewhat small, the numerical proportions in which the four types of leaf form occurred were very similar to those obtained for Seabrook's Black, as may be seen from Table VI.

TABLE VI.

Distribution of Leaf Types in Seedlings of Siberian selfed.

Number of Seedlings.	SR Leaf Type.	S Leaf Type.	R Leaf Type.	r Leaf Type.
78	49	9	17	3
Theoretical Expectation 9 : 3 : 3 : 1 ratio:	44	15	15	5

No differences were observable, at least as discernable by the eye unaided by actual measurements, between these four types of leaf form as they appeared among the seedlings of Siberian and among those of Seabrook's Black nor between the types of bushes which bore them.

2. *Vigour.* The seedlings were recorded during their third, fourth and fifth years for vigour. Very few of the bushes were noted as definitely dwarfs and fewer than 10 per cent. were of intermediate vigour in their fifth year.

3. *Bud Colour.* Of seventy-eight bushes examined for bud colour, during two seasons, all were either red budded or intermediate, the ratio of the former to the latter varying from equality to two to one. The behaviour of bushes of three of the leaf types was very similar but bushes of the fourth type (r) appeared to have somewhat less deeply pigmented buds.

4. *Form of the Buds.* The buds of these seedlings were largely intermediate in shape with compactly wrapped bud scales. About 20 per cent. of the

bushes had conical shaped buds and from 6 to 15 per cent. round shaped buds. From 2 to 20 per cent. of the bushes had raggedly wrapped bud scales while those of from 20 to 40 per cent. were intermediate. Little difference was found with regard to these characters between bushes of the four leaf types.

5. *Season of Coming into Leaf.* These seedlings were either early or mid season in time of bursting into leaf.

6. *Fruit.* (*a*) *Raceme Length.* Observations during two seasons showed that the racemes were largely of medium length. Bushes with long racemes were upon no occasion found while very few seedlings, less than 10 per cent., had short racemes. With reference to differences in raceme length between bushes of the four types of leaf form, in Table VII. are summaried the results of measurements of raceme length made upon these bushes. Ten racemes from each of seventy-five bushes were taken.

TABLE VII.

Average Raceme Lengths of Seedlings of Siberian selfed.

Leaf Type.	Number of Seedlings.	Average Length of Racemes.	Longest.	Shortest.
SR	49	37.0 mm.	54.0 mm.	20.0 mm.
S	9	40.9 mm.	49.5 mm.	34.0 mm.
R	16	34.3 mm.	46.5 mm.	16.0 mm.
r	1	24.0 mm.	—	—

As may be seen, the racemes of seedlings of the S. leaf type were somewhat longer, on the average, than those of the SR. leaf type, while those of bushes of the R. and r. types were somewhat shorter.

(*b*) *Quality.* The majority of these seedlings bore fruits which were of medium size. The flavour of the fruits, when it was estimated, was found to be medium in the case of seedlings of the SR. type and, generally speaking, acid in the case of the other types. In season of ripening the fruits of these seedlings were uniformly either mid season or late mid season.

7. *Cropping.* When estimates were made of the percentage of the flowers which matured fruits it was found that fewer than 2 per cent. of the bushes set more than 40 per cent. of their flowers while about 80 per cent. set 1 per cent. or fewer.

IV.—SEEDLINGS OF OTHER VARIETIES OF THE FRENCH GROUP—SELFED.

Parent Varieties. Resister, North Holland Black, Ogden's Black and Mammoth.

Characters : Similar to French Black. Hatton (1) says of Resister : " It is a typical member of this (the French) group " and of Mammoth that " the young bushes have notably deep purple buds."

First Generation.

Eighty-one seedlings comprising a single family of each of the four varieties selfed were studied.

1. *Leaf Characters.* When these varieties were selfed, the families which resulted were composed of seedlings of the two leaf types already fully described as segregating from French Black (Types A. and B.). The proportions were very variable owing to the small units of seedlings involved. So far as it was possible to observe, there was no difference in the bushes of either types, in the shape of the leaves or in other characters, as they appeared when derived from French Black or from these varieties.

In vigour these seedlings were somewhat variable. In bud colour and form they were similar to the parent varieties. They were invariably mid-season or late mid-season in time of bursting into leaf in the Spring. The seedlings were grubbed before they had commenced to crop and no data was, therefore, available as to their fruiting characteristics.

The seedlings of varieties of the French group, with which the preceding part of this paper has been concerned, show considerable features of genetical and botanical interest. Thus, varieties morphologically indistinguishable, as, for instance, French Black and Seabrook's Black, have shown a fundamental difference in the segregation which occurs, upon selfing, at least as regards leaf and other related characters. Until further, more extensive breeding work has been carried out, it is somewhat premature to press a Mendelian interpretation of these phenomena too closely, but that there is some evidence in favour of viewing them as phases of factor interaction is shown by the ratios obtained. The fact to be developed in the subsequent portion of the present paper, that no other variety whose selfed families have been studied, has given rise to abnormal offspring of the types which have been bred from those of the French group, adds additional interest to the story of the genetical interrelationships of varieties of this species.

Broadly speaking, these seedlings have retained, without material modification through two generations, the characters which typify the parental group. Thus, they were largely vigorous bushes, with reddish buds, conical in shape with compact scales ; late in season of bursting into leaf. The racemes were of medium length and the fruits were medium or small, acid in flavour and mid season in time of ripening. Finally, if the abnormal segregants, i.e., leaf types B., S., R. and r., be excluded, in general features of leaf shape, the parental characters were reproduced in their offspring to a marked extent.

V.—SEEDLINGS OF BOSKOOP GIANT—SELFED.

Parent Variety. Boskoop Giant.

Characters: Medium to large, spreading *bush,* sparsely branched; *buds, during winter, large, broad, blunt, pink to purplish in colour, scales compact,* buds protruding; *early in coming into leaf in the Spring*; *flower racemes* frequently single at the node, *long;* leaves large, lobes regular and obtuse, petioles long, leaf sinus deep; *fruit very large, moderately sweet, earliest in season, very subject to "running off."*

First Generation.

Altogether about 100 seedlings comprising four families were studied.

1. *Leaf Characters.* These seedlings bore leaves similar in all salient particulars to those of the parent variety. A few individuals were noted as having leaves with a somewhat flattish surface and shallow leaf sinus, but the majority of the seedlings were identical with the parent in leaf shape, venation and serrations.

2. *Vigour.* Observations extending over seven years have indicated that the seedlings were, upon the whole, moderately vigorous. While, at three years old, more than 30 per cent. of the bushes were described as dwarfs this proportion tended rapidly to diminish until at seven years old no bush remained in the dwarf class, while about 75 per cent. of the bushes were definitely vigorous.

3. *Bud Colour.* While the colour of the buds was by no means stable from year to year, upon an average of four distinct observations it may be said that they were largely red in colour with a small proportion, never greater than 8 per cent of seedlings with green buds.

4. *Form of the Buds.* The buds were largely either intermediate or round in shape with compactly wrapped bud scales. A small proportion, about 7 per cent., had buds of a conical shape while approximately two per cent. had buds with raggedly wrapped scales.

5. *Season of Coming into Leaf.* The seedlings were either mid season or late in time of bursting into leaf.

6. *Fruit.* (*a*) *Raceme Length.* Eye observations, later confirmed by actual measurements, have indicated very clearly that the racemes of these seedling bushes were by no means so long as those of bushes of the parent variety, of comparable age. In no year did more than 30 per cent. of the bushes have long racemes while those of about 5 per cent. were described as short.

(*b*) *Quality.* The fruits were described as either large or intermediate in size, predominantly of a medium flavour with an intermediate or, more rarely, a tender skin. They were early or mid-season in period of ripening.

7. *Cropping.* These seedlings were invariably described as considerably "run off." Whenever estimates of the proportion of the flowers which set fruits were made no bush was found which set more than 10 per cent. of its blossom. When weights of fruit were taken, they indicated that the quantity of fruit borne was negligible when compared with that borne by bushes of the parent variety growing under more favourable conditions and of comparable age.

8. *Big Bud.* A number of Big Buds were recorded upon these seedlings from time to time. No correlation whatever could be established between the severity of infestation and the shape of the buds or the wrapping of the bud scales of the seedlings concerned.

Second Generation.

Two families comprising 112 seedlings were studied.

1. *Leaf Characters.* The leaves of the seedlings of the second generation were apparently similar in all essential respects of shape, texture, etc., to those of the parent variety.

With regard to bud colour and form, these seedlings parallelled very closely those of the first generation and bushes of the parent variety. They had hardly reached a sufficient age to make it possible to say much as to their vigour.

Up till the time of their removal, these seedlings had not yielded sufficient fruit to make it possible to say anything as to their cropping performance or of the distribution of their fruiting characters.

The seedlings of both the first and second generations obtained by selfing this variety, retained in all salient respects the characters of the variety. They were of vigorous habit, with reddish buds, largely round in shape with compactly wrapped bud scales. The racemes, while, apparently, not so long as those of the parent variety, were, nevertheless moderately long; the fruits were large in size, of medium flavour with characteristically tender skins. Finally, the seedlings were unmistakably of the Boskoop type in the general characters of leaf shape and texture.

VI.—SEEDLINGS OF GOLIATH—SELFED.

Parent Variety. Goliath.

Characters: Medium sized, very erect *bush*; *buds, during winter, small* and often crowded, *conical and pointed, light green slightly tinged pink in colour, scales loosely arranged; early in coming into leaf; three to six flower racemes per node, often short;* leaves medium to smallish, lobes very irregular, petiole short, leaf sinus somewhat shallow; *fruit medium to large, sweet, mid-season, some "running off."*

First Generation.

Two hundred and twenty seedlings comprising two families were studied.

1. *Leaf Characters.* The leaves of the seedlings were identical in shape and texture with those of the parent variety. A few minor variations were noted among the leaves of some of the seedlings. A few of the bushes bore leaves somewhat yellowish in colour, the leaves of a few others were somewhat prominently veined, while short lobes or ragged marginal serrations were noted as characteristic of others.

2. *Vigour.* Four years' observations upon 220 seedlings of this variety have shown that the bushes were fairly vigorous, at least after they had reached the fully adult stage. While, at three years old, twenty per cent. of the bushes were described as dwarfs, this proportion had been reduced by the time they were eight years old to fewer than three per cent.

3. *Bud Colour.* The seedlings showed a high degree of variability for this character from year to year. The proportion of bushes with green buds varied from 40 per cent. to less than 3 per cent in different years. Bushes with reddish buds varied from 20 to 7 per cent. Upon the whole, the bushes had buds tinged to a greater or less extent with red.

4. *Form of the Buds.* While the larger proportion of the seedlings had conical buds with raggedly wrapped bud scales, a number of them had buds of an intermediate shape in each year, and in one year well over 20 per cent. of them had compactly wrapped bud scales.

5. *Season of Coming into Leaf.* The majority were either mid season or late in the period at which they burst into leaf in the Spring.

6. *Fruit.* (*a*) *Raceme Length.* Observations during three years indicated that the racemes were short in all but a very small proportion of cases. Of 177 seedlings only one was recorded as having long racemes, while from 1 to 3 per cent. only had racemes of medium length. Measurements of the raceme lengths of both the seedlings and the parent variety indicated that the racemes of the former were, on the average, very considerably shorter than those of the latter at a comparable stage in their growth. Although the parent variety normally bears from three to six racemes at each node, the racemes of the seedlings were borne, with very few exceptions, singly at the node.

(*b*) *Quality.* In size, the fruits were preponderantly intermediate with, however, a proportion, varying from 3 to 35 per cent. of large fruited bushes. In flavour they were, almost exclusively sweet with skins of medium texture. They were, with very few exceptions mid season in period of ripening.

7. *Cropping.* Whenever estimates of the extent to which these seedlings were subject to " running off " were made they were found to be either moderately or much subject to this trouble. Records of the proportion of the blossom which

set fruits, upon the single occasion on which they were taken, showed that only one out of 124 bushes set more than 20 per cent. of the blossom borne, while over 90 per cent. set 10 per cent. or less. Actual weighings of the crop, taken during three years, showed that the fruits produced by these seedlings were, upon the average only a fraction of those which have been obtained from bushes of similar age of the parent variety.

8. *Big Bud.* Considerable infestations of Big Bud were observed upon these bushes. There was little apparent connection between the severity of the trouble on particular seedlings and the shape of their buds or the manner in which the bud scales were wrapped.

Second Generation.

Only eight seedlings comprising a single family were studied.

1. *Leaf Characters.* All these seedlings showed a marked resemblance to the parent variety with regard to leaf characters, no notable deviations from the type being observed.

2. *Vigour.* These seedlings were all somewhat dwarf and stunted in growth. How far, however, this was inherent in the seedlings themselves and how far it may have represented their response to unsatisfactory environmental conditions cannot be determined but they were growing for some time upon a plot on which were vigorous young fruit trees in nursery rows at a short distance from them.

3. and 4. *Bud Colour and Shape.* The buds of all these seedlings were slightly tinged with red and were largely intermediate in shape with compactly wrapped bud scales.

These seedlings never bore either flowers or fruit.

The seedlings of Goliath of both the first and second generations were markedly similar to the parent variety. Thus, the bushes were moderately vigorous, the buds, during winter, were largely tinged with red, conical in shape with raggedly arranged bud scales. The fruiting racemes were generally short although, unlike the parent variety, they were usually borne singly at the node. The fruits were exclusively either medium or large in size, sweet flavoured and mid season in period of ripening. The leaves were, in shape and texture, recognisably of the parental type and it is noteworthy that the light green colouration of the leaves, a notable characteristic of the Goliath group, assumed an extreme form in a proportion of the seedlings.

VII.—SEEDLINGS OF BALDWIN—SELFED.

Parent Variety. Baldwin.

Characters: Dwarf, compact *bush; buds during winter, long and large, conical* and often pointed, *light green in colour, scales loose and ragged; early in* *coming into leaf;* usually two or three flower racemes per node, *of medium length, waved;* leaves flattish, dark green, medium to small in size, lobes regular and acute, petiole medium to long, leaf sinus usually deep; *fruit of medium size, somewhat acid, of late season, little subject to "running off."*

First Generation.

Three hundred and seventy seedlings comprising three families were studied.

1. *Leaf Characters.* Marked abnormalities or deviations from the parental type of leaf were not found. Upon the whole, the seedlings reproduced with great constancy the typical leaves of the parental variety. There were, however, occasional minor variations. A number of bushes, approximately one-seventh of the whole, had a notably flattish leaf sinus. About one-sixteenth of the bushes were described as having yellowish coloured foliage while a much smaller proportion were characterised by leaves with somewhat wavy margins.

2. *Vigour.* These seedlings were not particularly vigorous. Thus, of about three hundred bushes, observed during five years, about 15 per cent. remained as dwarfs, at least up till their seventh year while only about 50 per cent. could be described as vigorous at that age.

3. *Bud Colour.* Considerable variation occurred from year to year but the buds were, in the majority of cases, either green or intermediate in colour. A small proportion, usually about 2 per cent. and never exceeding 20 per cent., were described as reddish budded while the proportion of green budded bushes varied from 45 to 60 per cent. of the total population.

4. *Form of the Buds.* The buds were, with very few exceptions, conical in shape with raggedly arranged bud scales. About 10 per cent. of the bushes had buds intermediate in shape and in about 2 per cent. of cases they were rounded. About a quarter of the bushes had bud scales somewhat more compactly wrapped.

5. *Season of Coming into Leaf.* These seedlings were predominantly mid season in leaf break. A proportion, varying from 5 to 30 per cent. were early while a few bushes, never more than 3 per cent., were late.

6. *Fruit.* (*a*) *Raceme Length.* The greater number of these seedlings bore racemes either short or medium in length. In certain years a small proportion of them had racemes which were described as long. Measurements of the lengths of the racemes of the seedlings and of bushes of the parent variety indicated that, upon the average, those of the seedlings were somewhat shorter than those of bushes of the parent.

(*b*) *Quality.* In size, fruits of these seedlings were, in the majority of cases, either medium or small. A proportion, varying from 6 to 16 per cent. of the bushes had large fruits. The flavour was, in all but a small percentage of cases, medium while the skins were either medium or tough in texture. In season of ripening, the fruits were, in every case, either mid season or late.

7. *Cropping.* Observations of the extent of "running off" were made during two years. Of 316 seedlings examined, it was found that a proportion, varying from 28 per cent. in the earlier year to about 3 per cent. in the latter, were quite free from "running off," while about 14 per cent. of the bushes were very subject to this trouble. In the two years during which estimates were made of the proportion of the flowers which set fruits, about 3 per cent. of the bushes were found to have set 50 per cent. of their blossoms or more. On the other hand, almost 50 per cent. of the bushes set 1 per cent. of their flowers or less. Weighings of the fruit borne by these seedlings were made during three years. The aggregate crops were negligible in quantity.

8. *Big Bud.* Considerable numbers of Big Buds were observed upon these bushes at various times. No significant correlation between the severity of the attack and the bud characters of the seedlings infested was observable.

Second Generation.

Thirty-one seedlings comprising a single family were studied.

1. *Leaf Characters.* These seedlings bore leaves in every way resembling the variety Baldwin. A number were noted as having a somewhat less deep leaf sinus than the remainder but otherwise the leaves were typical of the variety.

2. *Vigour.* These seedlings made very unsatisfactory growth possibly owing to the fact that they were growing among vigorous nursery trees. All would have fallen into the intermediate or dwarf class by comparison with other seedlings of similar age.

With regard to bud colour and form and the season of breaking into leaf in the Spring, these seedlings resembled very closely those of the first generation.

Up till their fifth year, when they were discarded, these seedlings had never borne any flowers or fruit whatever.

It is of great interest to notice how closely the seedlings of this variety resembled the parent for the characters which have been considered. They were the least vigorous of any which have been studied, the buds were either green or only slightly tinged with red during the dormant season; they were conical in shape and the bud scales were raggedly arranged. Marked departures from the type of leaf shape and texture characteristic of the parent variety were not met with. The fruiting racemes were preponderantly of medium length, the fruits were either of medium size or small and of medium flavour, somewhat late in season of ripening.

ACKNOWLEDGMENTS.

The writer's grateful acknowledgments are due to Messrs. R. G. Hatton and J. Amos who have permitted him to make the fullest use of records collected by them upon many of these seedlings prior to his own association with this work. His especial thanks are also due to Mr. Hatton and to Dr. R. C. Knight for many useful suggestions and much helpful criticism in the compilation of this paper. Finally he is indebted to Mr. Amos for the photographs.

SUMMARY.

1. Details of observations extending over seven years, made upon seedlings of selfed families of the first and second generations of the chief varieties of black currants are summarised and discussed.

2. The behaviour of the seedlings with respect to the colour and form of the buds, season of leaf break and fruit maturity, length of the fruiting racemes, size and flavour of the fruits and texture of the fruit skin is dealt with. It is shown that the characters which were studied were transmitted without material modification to seedlings of the first and second generations.

3. It was found that, whereas Boskoop Giant, Goliath and Baldwin, when selfed, produced seedlings which bore leaves in all essential respects similar to those of the parent varieties, French Black and four closely allied varieties, produced, in addition to seedlings bearing leaves like the parent, a number which bore leaves of an abnormal shape. Seabrook's Black and Siberian, when selfed, gave rise to seedlings bearing two additional types of abnormal leaves as well as to bushes similar to those noted for French Black and bushes with leaves like those of the parent.

4. It is shown that none of these seedlings, with the possible exception of a small class segregating from varieties of the French group, gave rise to any new characters or combination of characters, of marked economic value.

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(*Received* 11/12/29.)

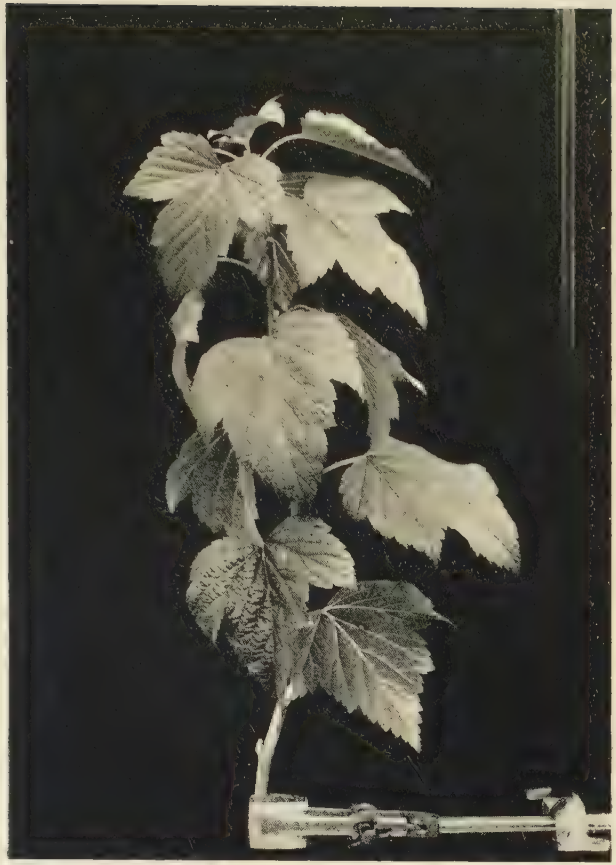


PLATE 1.
FRENCH BLACK SELFED.
Normal Leaf Type (A.).

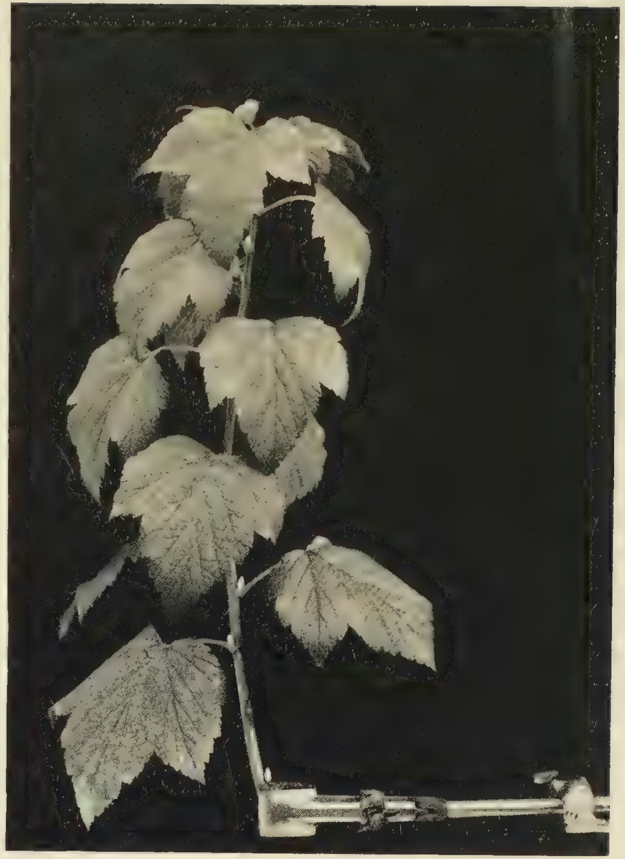


PLATE 2.
SEABROOK'S BLACK SELFED.
Normal Leaf Type (SR.).

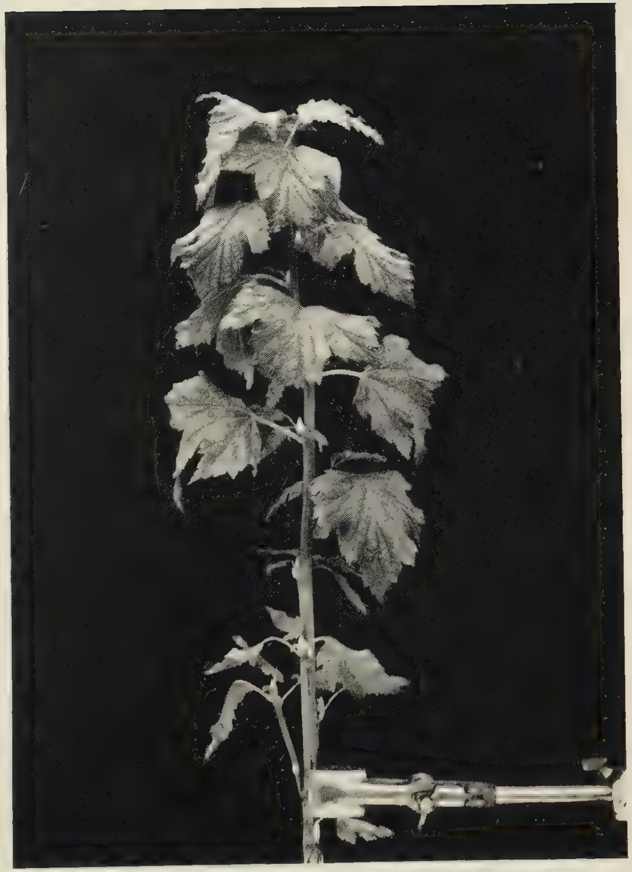


Plate 3.
FRENCH BLACK SELFED.
(Abnormal Leaf Type B.)

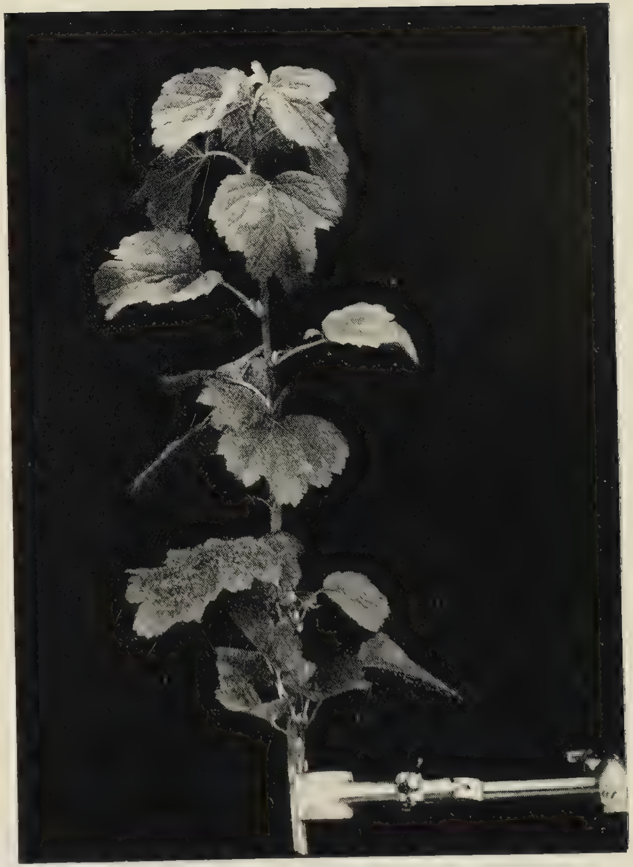


Plate 4.
SEABROOK'S BLACK SELFED.
(Abnormal Leaf Type R.)

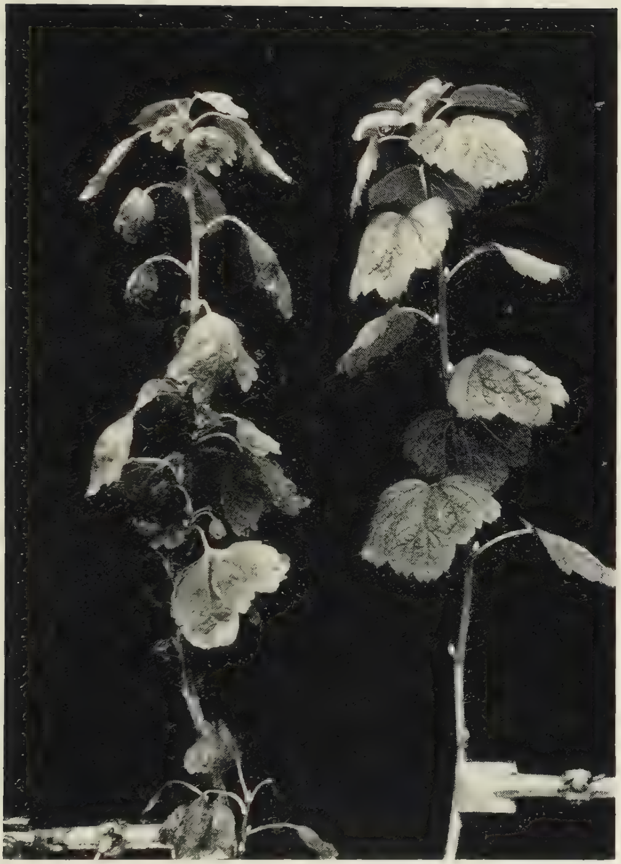


PLATE 5.

SEABROOK'S BLACK SELFED.

Abnormal Leaf Types, r. (left) and R. (right).

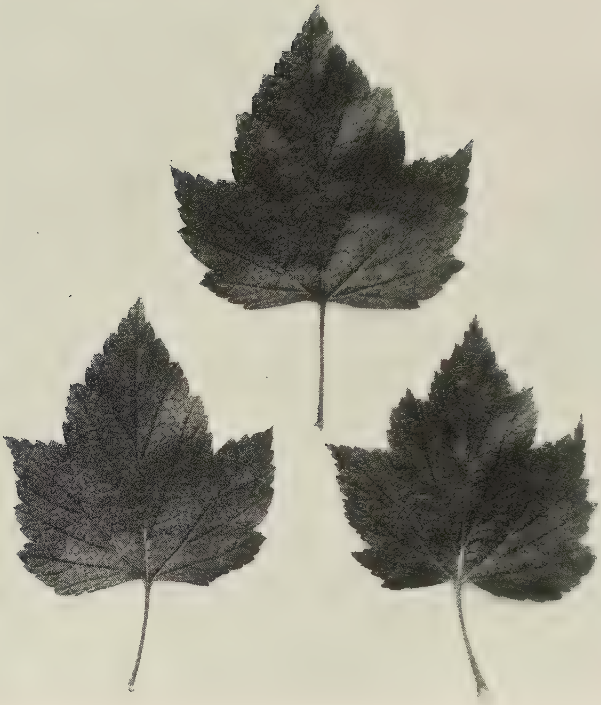
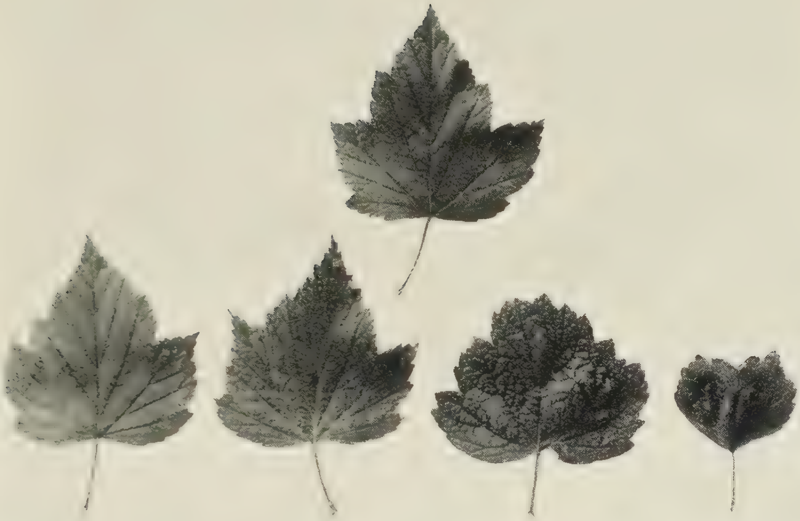


Plate 6.

LEAVES OF FRENCH BLACK.

Top: A Leaf of the Parental variety.

Below: Leaves of French Black selfed. Left: Normal (A.) type.
Right: Abnormal (B.) type.



(a) (b) (c) (d)

PLATE 7.

LEAVES OF SEABROOK'S BLACK.

Top : A Leaf of the Farental variety.

Below : Leaves of Seabrook's Black selfed. (a) Normal (SR.) type ; (b) Abnormal (S.) type ; (c) Abnormal (R.) type ; (d) Abnormal (r.) type.

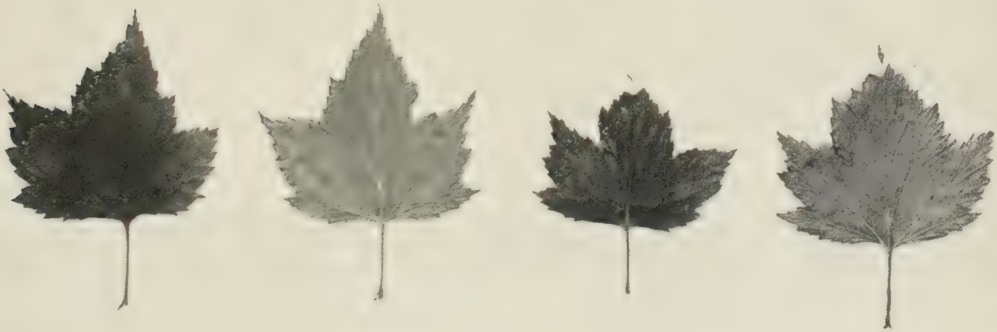


PLATE 8.

TYPICAL LEAVES OF FRENCH BLACK SELFED (B. type) AND SEABROOK'S BLACK SELFED (S. type).

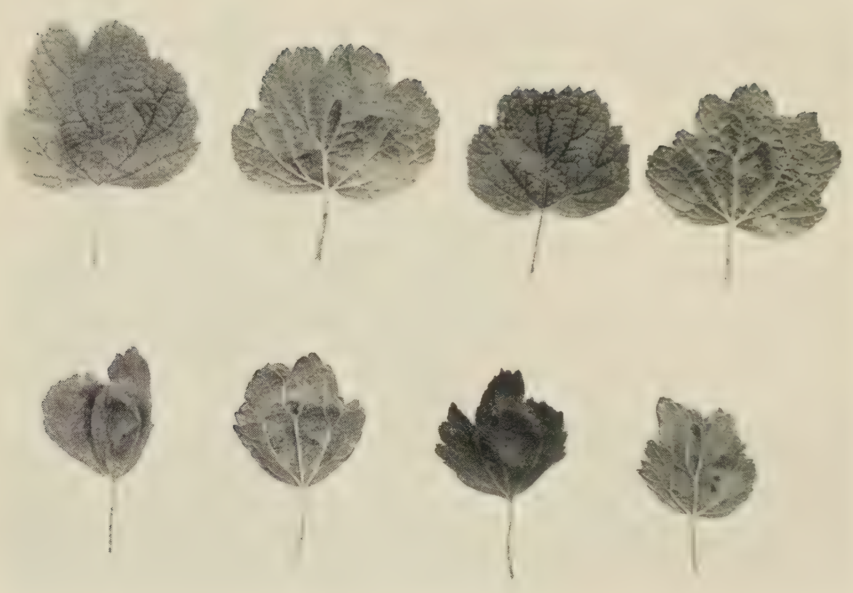


Plate 9.

TYPICAL LEAVES OF SEABROOK'S BLACK SELFED (R. and r. types).

(Above) R. type leaves; (Below) r. type leaves.

INVESTIGATIONS ON EGG-KILLING WASHES AT THE LONG ASHTON RESEARCH STATION.

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Introduction.

The investigation of tar-distillate spray fluids as egg-killing washes was commenced at Long Ashton in 1921, when a supply of a product of this nature in use in Holland with apparent success was obtained from that country, as a result of the visit of a member of the Staff of this Research Station to that country. Analysis showed this product to contain about 80 per cent. of a tar-distillate, the remainder of the mixture consisting of a resin soap and water. The tar-distillate boiled, for the most part, from about 190°-360° C. and contained about 10 per cent. of its weight of "tar acids" (cresols, etc.).

Laboratory tests were carried out with this wash, Aphis eggs being employed for the purpose. The success of these experiments led to field trials being instituted during 1922 and succeeding years and highly promising results were obtained.

By the year 1924 several proprietary spray fluids of this nature of British manufacture had also appeared on the market, and further field trials, on a wider scale, proved the efficacy of certain of these as a control for such pests as Aphis, Apple Sucker (*Psylla mali*) and to some extent for Lepidopterous larvæ. No control, however, had been effected up to this stage of the very serious Apple Capsid Bug (*Plesiocoris rugicollis*).

In 1925, therefore, further tests of the more efficient spray mixtures were undertaken, using them at somewhat greater concentrations. As a result some indications were obtained of control of Capsid Bug, together also with an increase in the control of caterpillars.

During the winter of 1925 field trials were repeated for the specific purpose of obtaining still further information regarding Capsid Bug control. In this particular series the results were very striking and it seemed as though the problem might be solved by the application of a good tar-distillate wash at 10 per cent. strength, so long as it was applied to the trees as late as possible during the dormant period. The following season (1926) trials designed to confirm these findings were initiated. These however did not bear out the results of the previous year. A series of laboratory tests carried out during this period in connection with the effects of rain following the application of such washes, showed that the reason for the above mentioned failure was due, in all probability, to such adverse weather conditions, resulting in an appreciable proportion of the mixture which had been applied to the trees being washed off by rain.

THE COMPOSITION OF TAR-DISTILLATE WASHES IN RELATION TO TOXICITY.

Since a tar-distillate such as that used in the preparation of the above-mentioned winter wash obtained from Holland consisted of a complex mixture of compounds, it seemed highly probable that the various components would differ in their power of killing insect eggs. In the Autumn of 1921, a sample of a tar distillate of similar boiling point was obtained and separated, to some extent, into its various components. It was then sought to emulsify the various products obtained, but satisfactory emulsions could not, at first, be prepared. Some preliminary trials against eggs of the permanent apple aphis, however, appeared to indicate that the portion of the distillate of higher boiling point was the most toxic, and, moreover, that such a product when deprived of " tar acids " appeared to be at least as toxic to the eggs, if not more so.

It was not possible at that time, however, to give detailed attention to the problem of the proper emulsification of these tar-distillate products, but in the autumn of 1925 special facilities were provided for the work by the aid of a grant from the Ministry of Agriculture and Fisheries. A short account of the investigation then conducted has already been published by Dr. L. E. Smith (7). This investigation rendered it evident that it was desirable to investigate more fully the egg-killing properties of certain products obtained from the tar distillate and, for this purpose, a further grant was subsequently made by the Ministry. The results of this new work were published in the Annual Report of the Long Ashton Research Station (Tutin 8) and may be summarised as follows.

Toxicity towards Winter Moth Eggs of Various Tar Products.

The material employed for the greater part of this work was a vertical retort tar boiling from 190° to 360° C. and which contained nearly 20 per cent. of " tar acids." Some basic material (quinoline, etc.) was also present in the the tar-distillate but this was removed, and not further examined, since these bases are known to be practically valueless for egg-killing purposes. The " tar-acids " were then separated from the neutral material and both of these products were submitted to fractional distillation. The neutral material was divided into two fractions; one boiling from 190°-280° and the other from 280°-360°. The lower boiling material, on cooling, deposited napthalene, whilst that of higher boiling point yielded anthracene. Both these solid products were removed, the liquid portions of the distillate only being employed for the subsequent experiments and are referred to later as the " low neutral " and " high neutral " respectively.

The " tar acids " were separated into four fractions, boiling respectively from about 190°-220° C.; 220°-250° C.; 250°-280° C.; 280°-360° C. The two intermediate fractions were relatively small and were not further employed. The fraction boiling at 190°-220° C. consisted essentially of cresols and is referred to subsequently as the " low phenols " ; that boiling from 280°-360° C. is referred to as the " high phenols."

For the purpose of ascertaining the relative toxic properties of these products, five emulsions were prepared with the aid of castor oil soap :—

1. An emulsion of the total distillate. This is a product comparable to the tar distillate spray liquids at present in use.
2. An emulsion of the " low neutral."
3. An emulsion of the " high neutral."
4. An emulsion of the " low neutral " +20 per cent. of " low phenols."
5. An emulsion of the " high neutral " +20 per cent. of the " high phenols."

The products were tested against eggs of the Small Winter Moth. A large number of tests were made, about 5,000 eggs being employed. Six batches of eggs kept as controls gave hatches varying from 80-100 per cent., the average being over 90 per cent. The emulsions were employed in two concentrations, 5 per cent. and 8 per cent. The results obtained are summarised in the following Table :—

	Emulsion I.		Emulsion II.		Emulsion III.		Emulsion IV.		Emulsion V.	
Strength	5%	8%	5%	8%	5%	8%	5%	8%	5%	8%
Percentage hatch ..	2.9	1.5	3.2	0.4	0.0	0.0	13.9	1.9	0.3	0.0

These results are entirely in harmony with results of a preliminary nature which had previously been obtained by smaller-scale trials against eggs of the Permanent Apple Aphis. Other batches of winter moth eggs were also sprayed at the same time with one of the best-known brands of " carbo " washes and with the dinitro-cresol preparations supplied from the Rothamsted Research Station. The results clearly showed the superior egg-killing powers of the above-described

Emulsions III. and V., the nitro-products in particular being relatively ineffective against Winter Moth eggs.

Two outstanding conclusions may be drawn from these results: Firstly, that the portion of the tar-distillate boiling *above* 280° C. is more toxic to eggs than is the material of lower boiling point or the total distillate; and, secondly, that the addition of phenols (" tar acids ") to the neutral materials actually *lowers* the toxicity of the product. The material most toxic to eggs is therefore seen to be the liquid, neutral constituents of the tar-distillate boiling between 280° and 360° C.

A New Method of Emulsification.

The above-described experiments having shown clearly that the portion of the tar-distillate having the greatest egg-killing powers is the neutral constituents of high boiling point, it was therefore considered desirable to devise a method by which this neutral product could be emulsified in a satisfactory manner.

In the preparation of the above emulsions, considerable difficulty was experienced with the products consisting of neutral materials only. Castor oil soap was found to be the most efficient soap that could be obtained, but even when employing this it was found only just possible to prepare emulsions that were sufficiently stable for the above-described trials against Winter Moth eggs. An emulsion of the neutral material sufficiently stable to be employed on the commercial scale could not be prepared by the employment of any soap. This is owing to the fact, rendered evident by the work of Dr. Smith (*loc. cit.*), that the preparation of a tar-distillate spray liquid which will yield a good emulsion on dilution with water depends on the establishment of a certain balance between the particular soap solution used and the " tar acid " content of the tar-distillate, whereas the product which it was now sought to emulsify was devoid of " tar acids." It was therefore necessary to find a new emulsifying agent that would give the desired result. The behaviour of a number of products was investigated but the most convenient emulsifier that was found was a sulphonated oil known as Agral W.B., a product by means of which it was found that a perfect emulsion could quickly be prepared of any neutral liquid immiscible with water.

In practice it was found that the most convenient way of preparing good emulsions by means of Agral W.B. was as follows: Ten parts (by volume) of Agral W.B. were thoroughly mixed with 90 parts of the neutral tar oil. This mixture was then poured into the desired volume of water, after which some caustic soda, previously dissolved in a little water, was introduced, and the mixture stirred. When working with distilled water, or a very soft water, it was found that perfect emulsions could be obtained when the proportion of Agral W.B. was only 5 per cent. of the tar oil mixture. In the case of really hard waters, however, it has been found necessary to use a mixture containing as much as 15 or 20 per cent. of Agral W.B., whilst with certain of the exceptionally saline waters occurring in the Wisbech area even 20 per cent. of Agral W.B. was found insufficient.

The amount of caustic soda that should be added bears a direct relationship to the amount of Agral W.B. present in the mixture but is independent of the proportion of water used. When using rain water and a tar oil mixture containing 10 per cent. by volume of Agral W.B. the addition of about 1.5 ozs. of caustic soda per gallon of the tar oil concentrate will result in perfect emulsification ; moreover, the amount of alkali added may be increased up to about nine times this amount and good emulsions still be obtained. When using harder waters, however, the upper permissible limit of alkali becomes lowered, but the minimum amount that should be used remains the same. In practice, the authors have found it convenient to use 2 ozs. of caustic soda per gallon of concentrate containing 10 per cent. of Agral W.B., or 3 ozs. per gallon when using a concentrate containing 15 per cent. of Agral W.B. If appreciable amounts of "tar acids" are left in the "neutral" oil which is to be emulsified the permissible range of alkali again becomes narrowed down in a manner somewhat similar to that which occurs with a hard water. The foregoing observations apply primarily to the preparation of 10 per cent. emulsions of the tar oil concentrate. If it is desired to employ more dilute emulsions it must be borne in mind that it may be necessary to use a concentrate containing a higher percentage of Agral W.B. than would be necessary for the formation of satisfactory 10 per cent. emulsions. In all cases, however, the amount of alkali used should bear the same relationship to the amount of Agral W.B. present.

The fact that good emulsions, when prepared in the manner described above, remain stable on long exposure to the air and consequent saturation with carbon dioxide indicated that washing soda might be used in chemically equivalent amount in place of the caustic soda which had been employed. This was found to be the case but, in the majority of cases, it has been found more convenient to employ the caustic alkali owing to the much greater facility with which it dissolves in water.

By the employment of Agral W.B. it was therefore found possible to prepare, in a few moments, perfectly stable emulsions of the neutral tar oil products. Such an emulsion, in 4 per cent. strength, of the neutral tar oil fraction boiling from 280°-360°C. was therefore prepared and its toxicity towards insect eggs was compared with that of one of the best-known brands of tar-distillate washes in 4 per cent. strength. The eggs employed in this case were those of the "Ringlet" butterfly. It was then found that the emulsion of the neutral product killed 98 per cent. of the eggs, whilst the commercial wash killed only 45 per cent., thus again showing the much greater toxicity of the high boiling, neutral material. It was also found that the emulsion of the high boiling, neutral material was slightly less toxic to growing vegetation than was a corresponding emulsion prepared from the total tar-distillate containing " tar acids."

Experiments and observations in the field have also rendered it apparent that the emulsion of the high boiling, neutral material prepared by means of Agral W.B. yields a much more permanent and satisfactory coating when applied to the twigs of trees than does an emulsion of the older type of tar oil wash prepared from the total tar-distillate. Treatment with the former emulsion produces on the twigs a somewhat varnish-like coating, which does not appreciably evaporate and is not washed off by rain. When emulsions prepared from a total tar-distillate are employed, however, a considerable portion of the material evaporates, owing to its relatively high volatility, whilst the " tar acids " present are not only themselves washed off by rain but, in being so removed, take with them an appreciable amount of neutral material which would otherwise have remained on the tree and been available for the destruction of insect eggs.

In consequence of the results described above fresh series of field trials were undertaken and carried out during the winter spraying season 1927-28, and again, on a much more extensive scale, during 1928-29, these latter being carried out by means of a Special Investigation Grant from the Ministry of Agriculture and Fisheries. Those of 1927-28 were conducted in one district of the Bristol Province, whilst in 1928-29 the centres were so selected as to embrace all the principal fruit-growing areas of England, in order that the sprays employed should thoroughly be tested under varying conditions.

FIELD TRIALS 1927-28.

These trials were situated in the Cheltenham district. Two washes were tested—a mixture containing 90 parts of the high-boiling neutral tar oil and 10 parts of Agral W.B., made up at the Long Ashton Research Station in accordance with the investigations already dealt with (hereinafter referred to as a " high neutral " spray), and a well known proprietary brand of tar wash, employed for purposes of comparison (which will be referred to as " standard " spray). Whilst the general purpose of the trials was to obtain information regarding the relative efficiency of these two types of egg-killing washes, it was hoped that they would, in particular, clarify the position with regard to control of the Apple Capsid Bug (*Plesiocoris rugicollis*) in the egg stage.

Trials were instituted at three centres, where in each case the variety of apple treated was Newton Wonder. On the whole the sprays emulsified well, but at Centre I., the " high neutral " spray did not emulsify in a perfectly satisfactory manner. An analysis subsequently showed this to be due to unforeseen quantities of sulphates present in the water employed in mixing. Even in this case the final results were of a high order.

Capsid Bug and caterpillars were present at all three centres; Aphis was absent from all. There was a moderate attack of Psylla at Centre II.

CENTRE I. Cheltenham. Variety of Apple, Newton Wonder (12 year old) trees.

Treatments.

(a) *Single Sprayings.*

10 per cent.	Long Ashton spray	23 trees.
6 ,,	,, ,,	10 ,,
10 ,,	Standard Wash	10 ,,
6 ,,	,,	10 ,,

Date of Application: February 8th, 1928.

(b) *Double Sprayings.*

5 per cent.	Standard wash	followed by	5 per cent.	Standard wash.
5 ,,	,,	,,	10 ,,	,,
10 ,,	,,	,,	5 ,,	,,

10 trees in each treatment.

Dates of Application: First spraying February 8th, 1928. Second spraying, February 22nd, 1928.

(c) *Controls.*

Six trees in each control four times repeated.

Methods of Estimation of Crop Damage.

The system of marking employed was the same as that used in 1925 and 1926. The method, which did not attempt to differentiate more finely than an estimated 10 per cent. was as follows. Each block of trees subjected to a given treatment was inspected as a whole, and then marked with a number from 0 to 5 according to the following scale:

0 = no pest present.
1 = pest very slight.
2 = pest slight.
3 = pest moderate.
4 = pest bad.
5 = pest very bad.

In cases of indecision, an intermediate figure was given. All the figures were then doubled; "very bad" thus received 10, whilst lesser intensities of attack were allotted correspondingly smaller numbers.

TABLE I.

Variety.	Treatment.	Caterpillars.	Capsid Bug.
Newton Wonder.	Control I.	6	8
	10% S. 5% S.	4	6
	5% S. 10% S.	2	4
	Control II.	6	8
	5% S. 5% S.	2	4
	Control III.	4	6
	10% HN.	0	1
	Control IV.	4	8
	10% S.	1	2
	6% HN.	1	1
	6% S.	1	1
	Average of 4 Controls	5	7·5

HN=" high neutral " spray.

S=proprietary wash used as standard.

In that portion of the trial where the sprays were applied at a strength of 6 per cent., the infestation of Capsid Bug was less severe than elsewhere, and is reflected in the counts.

Dates of Examination : Examinations were made on April 23rd, May 17th and June 18th.

Results.

The fruit crop at this centre was light owing to severe injury by late frosts. At the examination on June 18th therefore all fruit present on the plots was enumerated. All fruits bearing any recognisable Capsid markings, however slight, were regarded as damaged fruits ; as a result a considerable proportion of saleable fruit was included under this category. The figures obtained are shown in Table II.

TABLE II.

Treatment.	No. of Fruits counted.	No. of Apples marked by Capsid Bug.	Percentage of marked Apples.
Control I.	45	38	84
10 per cent. HN.	179	35	19
Control II.	9	9	100
10 per cent. S.	34	17	50
Control III.	No fruit present.	—	—
6 per cent. HN.	13	1	7
6 per cent. S.	38	13	33
Control IV.	6	2	33

CENTRES II. AND III.

The general plan of the sprayings at these two centres was similar to that at Centre I., except that no double sprayings were carried out, and that at Centre III. the sprays were all used at 10 per cent. (See Tables III. and IV.)

No difficulty was experienced with emulsification of spray mixture at either of these centres, but at both the trees had suffered from frost damage, more particularly at Centre III.

TABLE III.

Treatment.	No. of Fruits counted.	No. of Apples marked by Capsid Bug.	Percentage of marked Apples.
Control	350	281	80
10 per cent. HN. ..	137	21	15
6 per cent. HN. ..	100	40	40
10 per cent. S.	244	144	60
6 per cent. S.	64	48	75

TABLE IV.

Treatment.	Caterpillar.	Capsid Bug.
Control	1	7
10 per cent. HN.	0	2
10 per cent. S.	0	2

FIELD TRIALS, 1928-29.

During this season the trials were extended to include plums and black currants in addition to apples. Those on apples were designed to obtain confirmation of the satisfactory initial results obtained during 1927-28.

Plums were included in the hope that the use of "high neutral" spray might, owing to its greater efficiency, prove capable of controlling caterpillar and aphis at lower concentrations than those at which the older types of tar-distillate sprays are used.

Black Currants were treated on account of the serious increase in injury by Capsid Bugs (chiefly *Lygus pabulinus*) which has been observed during recent years in the case of this fruit.

1. *Apples.*

Trials were situated at eleven centres in nine counties and included the following varieties :—Allington, Bramley, Bismarck, Cox's Orange Pippin, Early

Victoria, Grenadier, Jubilee, James Grieve, King Edward, Lane's Prince Albert, Lord Derby, Newton Wonder and Prince's Pippin. In all cases the trees were growing under commercial conditions.

Treatments.

The following three washes were tested :

(*a*) " High neutral " spray as employed in 1927-28 trials, using however, double the amount of emulsifier then utilised in order to overcome emulsification difficulties experienced with certain types of water ; hereafter denoted as H.N.(A).

(*b*) A modification of the above, denoted H.N.(B), prepared by a commercial firm, in which the tar distillate used was identical with that employed in the preparation of the H.N.(A) wash, but in which the method of emulsification differed.

(*c*) A well known proprietary brand of tar-distillate wash used as a " standard " (S), as in 1927-28.

Dates of Application.

1. *Apples.*

The dates of application ranged from January 17th to March 9th, 1929. It will be noted in Table V. that, at the first three centres, two dates are given ; this is due to the fact that certain difficulties arose in connexion with the delivery of the H.N.(A) wash. The earlier date in each case refers to the application of the H.N.(B) wash and the later to that of the H.N.(A) wash. It may be recalled that exceptionally bad weather conditions prevailed practically throughout the period of application, and as a result considerable difficulties in the satisfactory application of the washes were experienced.

In the lay-out of trials, control plots were duplicated or triplicated so as to have unsprayed plots available for comparison in the immediate vicinity of any particular sprayed plots.

2. *Plums.*

Trials were situated at three centres.

The dates of application were February 1st and February 11th, 1929.

3. *Black Currants.*

Trials were carried out at three centres.

The sprays were applied on the following dates : Centre I.—February 4th ; Centre II.—February 1st ; Centre III.—February 21st.

Strengths of Washes.

The strengths employed for the three washes were as follows :—

1. *Apples.*

Proprietary wash used as " standard " (S) :—12 and 10 per cent. strengths.
Modification of "high neutral" wash (H.N.(B)) :—12, 10 and 6 per cent. strengths.
" High neutral " wash (H.N.(A)) :—10, 8 and 6 per cent. strengths.

2. *Plums.*

Proprietary wash used as " standard " (S) :—6 per cent. strength.
Modification of "high neutral" wash (H.N.(B)) :—6 and 3 per cent. strengths.

3. *Black Currants.*

Proprietary wash used as " standard " (S) :—10 per cent. strength.
Modification of " high neutral " wash (H.N.(B))— : 10, 6 and 3 per cent. strengths.
" High neutral " wash (H.N.(A)) :—10 and 6 per cent. strengths.

Methods of Estimation of Results.

1. *Apples.*

(*a*) *Estimation of injury to leaves and young fruits.* The methods of estimation of results were as follows. In the case of Capsid Bug, estimations by eye were made first of all ; these were followed, in the majority of cases, by actual counts made by means of tally registers. A random sample of 500 was taken as the standard number, but where any such count did not closely agree with the previous eye estimate, further samples of 500 or more were taken. This method was applied in the first place to trusses for the estimation of leaf damage (Table V.), and later to fruitlets for Capsid Bug markings (shown in Table VI.). The results for mature fruit, together with crop weights, will be found in Tables VII. to XIII., and were ascertained as described below.

(*b*) *Estimation of Injury to mature fruits.* The methods employed in obtaining the results here given were as follows :—

> Eye estimations were omitted and all figures are the result of actual countings and weighings of the complete crop from trees. All counts were made by means of tally registers. Samples of 1,000 fruits were taken as the standard number, and the percentage figures given are the result of the counts of these samples.
>
> In some instances, the entire crop on each plot was dealt with, but often it was necessary to restrict the fruit to that from a limited number of trees. In certain cases, where there was a marked difference in

the size of trees on any given plot, adjustments were made in the number of trees from which the crop was picked in order to obtain cropping tree surfaces as nearly equal as possible. Further, this principle had to be applied to certain groups of control trees on which the crop was very light in order to get enough fruit for counting purposes.

The fruit was graded into two samples: Those apples showing definite Capsid Bug injury, whether pronounced or slight only; and those entirely free. Such rigorous methods resulted in some perfectly marketable fruit being relegated to the former class, although the bulk of fruit in that class was, in most cases definitely unsaleable. Without such a vigorous grading no complete and reliable figures of Capsid Bug damage could have been obtained. The samples from each plot were weighed separately, after grading into the two classes mentioned, the sum of these two figures being the total crop weights from the trees used.

2. *Plums.*

Eye estimations only were made.

3. *Black Currants.*

A.—*Capsid Bug.* Eye estimation of percentage of leaves marked.

B.—*Aphis.* Eye estimations of infested leaves.

Results.

A.—*Apple Capsid Bug* (*Plesiocoris rugicollis*).

(*a*) *Injury to leaves and young fruits.* These are set out in Tables V. and VI., and are stated respectively as a percentage of trusses and young fruits marked.

The following diagram shows graphically the lay-out of the trials, and the results obtained at Centre I.

DIAGRAM I.

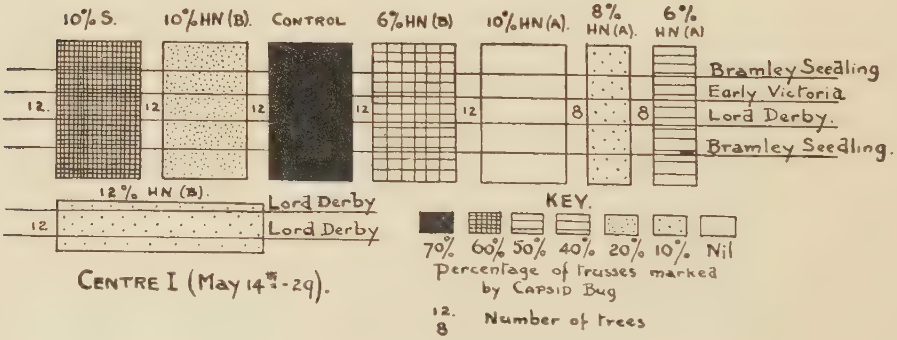

10% S.
10% HN (B).
CONTROL
6% HN (B)
10% HN (A).
8% HN (A).
6% HN (A)
12.
12
12
12
12
8
8
Bramley Seedling
Early Victoria
Lord Derby.
Bramley Seedling.
12% HN (B).
12
Lord Derby
Lord Derby
CENTRE I (May 14th-29).
KEY.
70%
60%
50%
40%
20%
10%
Nil
Percentage of trusses marked by CAPSID Bug
12.
8
Number of trees

TABLE V.

Apples. (Capsid Bug Markings on Trusses.)

Centre and Total Number of Trees.			Date.		Percentage.								
			Application.	Examination.	Controls.	12% S.	10% S.	12% H.N.(B)	10% H.N.(B)	6% H.N.(B)	10% H.N.(A)	8% H.N.(A)	6% H.N.(A)
I.	Stawell (Somerset).	88	Jan. 22 Feb. 6	May 14	70	—	60	10	20	50	0	10	40
II.	Cropthorne (Worcs.).	53	Jan. 17 Feb. 22	May 6	30	—	10	—	5	10	Trace	—	5
III.	Hampton (Worcs.).	85	Feb. 11 Feb. 22	May 6	76	—	50	—	10	40	0	—	10
IV.	Newnham (Glos.).	80	Feb. 4-5	May 13	23	—	16	—	Trace	23	0	—	12
V.	Topsham (Devon).	32	Feb. 8	June 12	40	—	30	—	Trace	—	Trace	—	—
VI.	Falmouth (Cornwall).	84	Feb. 6	June 13	Trace	—	Trace	—	Trace	—	0	—	—
VII.	Crockenhill (Kent).	154	Mar. 8	May 24	13	—	10	—	Trace	—	0	—	—
VIII.	Wilmington (Kent).	144	Mar. 9	May 24	93	—	30	—	5	—	10	—	—
IX.	Sompting (Sussex).	168	Feb. 23	May 23	52	—	50	—	14	21	—	—	—
X.	Friday Bridge (Isle of Ely).	40	Mar. 6-7	May 28	42	18	35	6	10	—	—	—	—
XI.	Burwell (Cambs.) A.	84	Mar. 6	May 29	30	10	8	6	8	—	—	—	—
	Burwell B.		Mar. 8	May 29	16	—	7	—	7	—	—	—	—

TABLE VI.

Apples (Capsid Bug Markings on Fruitlets).

Centre and total number of trees.	Date.		Percentage young fruit marked by Capsid Bug.					
	Application.	Examination.	Controls.	10% S.	10% H.N. (B).	6% H.N. (B).	10% H.N. (A).	6% H.N. (A).
II. Cropthorne (Worcs.) 53	Jan. 17 Feb. 22	June 18	66	40	18	30	6	26
III. Hampton (Worcs.) 85	Feb. 11 Feb. 22	June 17	55	43	8	32	5	26
IV. Newnham (Glos.) 80	Feb. 4-5	June 17	66	38	10	23	4	12
V. Topsham (Devon) 32	Feb. 8	June 12	90	50	5	—	Trace	—

Diagram II. illustrates the results obtained on fruitlets and the lay-out of the trial at Centre II.

DIAGRAM II.

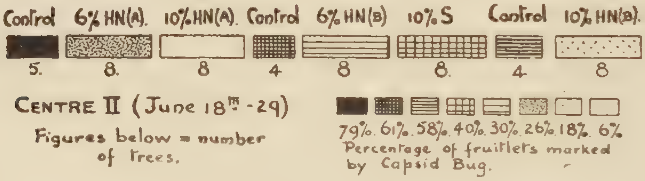

Control 6% HN(A). 10% HN(A). Control 6% HN(B) 10% S Control 10% HN(B).
5. 8. 8 4 8 8. 4 8
CENTRE II (June 18th -29)
Figures below = number of trees.
79%. 61%. 58%. 40%. 30%. 26%. 18%. 6%
Percentage of fruitlets marked by Capsid Bug.

TABLE VII.

Centre II.—Cropthorne, Worcestershire.

Dates of Application of Washes : January 17th, February 22nd, 1929.

Date of final examination : September 27th, 1929.

Variety.	Treatment.	Percentage number of fruits marked by) Capsid Bug. Per cent.	Weight of fruit marked by Capsid Bug. lb.	Weight of fruit unmarked by Capsid Bug. lb.
Lane's Prince Albert.	Control (9)	90	88	10
	10 per cent. S. (4)	87	112	27
	10 per cent. H.N.(B.) (5)	52	73	104
	10 per cent. H.N.(A.) (6)	11	18	106
	6 per cent. H.N.(B.) (5)	82	46	33
	6 per cent. H.N.(A.) (5)	45	177	233

Total number of trees included in this trial: 53.

(b) *Injury to mature fruits.* Late frost damage, unfortunately, resulted in absence of fruit from three of these centres (Isle of Ely, Cambridge and Somerset). At another centre (Cornwall) fruit records were not dealt with because the attack of Capsid Bug there was extremely light. Owing to local factors which were found to have complicated the results at the Sussex centre, this is also omitted. At the remaining six centres both good crops of fruit and incidence of the pest rendered these trials a thorough test. The results obtained at these centres are therefore set out in Tables VII. to XIII. The figures in brackets refer to the number of trees from which the fruit was obtained.

TABLE VIII.

Centre III.—Hampton, Worcestershire.

Dates of application of washes: February 11th, February 22nd, 1929.

Date of final examination: September 26th, 1929.

Variety.	Treatment.	Percentage number of fruits marked by Capsid Bug. Per cent.	Weight of fruit marked by Capsid Bug. lb.	Weight of fruit unmarked by Capsid Bug. lb.
Prince's Pippin.	Control (2)	90	36	5
	10 per cent. H.N.(A.) (4)	8	27	266
	6 per cent. H.N.(A.) (3)	51	47	60
Lane's Prince Albert.	Control (6)	70	71	34
	10 per cent. S. (6)	74	55	32
	10 per cent. H.N.(B.) (6)	14	10	51
	6 per cent. H.N.(B.) (6)	59	100	66

Total number of trees: 85.

TABLE IX.

Centre IV.—Newnham, Gloucestershire.

Dates of application of washes: February 4th and 5th, 1929.

Date of final examination: September 30th, 1929.

Variety.	Treatment.	Percentage number of fruits marked by Capsid Bug. Per cent.	Weight of fruit marked by Capsid Bug. lb.	Weight of fruit unmarked by Capsid Bug. lb.
King Edward VII.	Control (12)	60	24	25
	10 per cent. S. (12)	75	73	28
	10 per cent. H.N.(B.) (8)	24	62	230
	10 per cent. H.N.(A.) (8)	11	29	240

Total number of trees: 80.

Table X.

Centre V.—Topsham, Devonshire.

Date of application of washes: February 8th, 1929.

Date of final examination: September 23rd, 1929.

Variety.	Treatment.	Percentage number of fruits marked by Capsid Bug. Per cent.	Weight of fruit marked by Capsid Bug. lb.	Weight of fruit unmarked by Capsid Bug. lb.
Lane's Prince Albert.	Control (4)	65	270	160
	10 per cent. S. (4)	36	100	270
	10 per cent. H.N.(B.) (8)	11	10	130
	10 per cent. H.N.(A.) (4)	2	10	470

It should be noted, in relation to the above table, that the crop was taken from eight trees in the case of those sprayed with H.N.(B.) spray at 10 per cent. strength. This was done in an attempt to compensate for the small size of the trees.

Total number of trees: 32.

Table XI.

Centre VII.—Crockenhill, Kent.

Date of application of washes: March 8th, 1929.

Date of final examination: September 17th, 1929.

Variety.	Treatment.	Percentage number of fruits marked by Capsid Bug. Per cent.	Weight of fruit marked by Capsid Bug. lb.	Weight of fruit unmarked by Capsid Bug. lb.
Bismarck.	Control (6)	64	214	159
	10 per cent. H.N.(B.) (6)	8	25	320
	10 per cent. H.N.(A.) (6)	3	9	377
Lord Derby.	Control (6)	76	184	56
	10 per cent. S. (6)	95	337	31
	10 per cent. H.N.(B.) (6)	30	233	170

Total number of trees: 106.

We are indebted to Mr. M. D. Austin, of the South-Eastern Agricultural College, for kindly furnishing us with the following figures relating to the grading and weighing of the fruit from trees of the variety, "Allington Pippin" which had been sprayed with our preparations at this centre. Only weights were taken, no counts being made. The results are tabulated below.

Table XII.

Variety.	Treatment.	Percentage Weight of fruit marked by Capsid Bug. Per cent.	Weight of fruit marked by Capsid Bug. lb.	Weight of fruit unmarked by Capsid Bug. lb.
Allington Pippin.	Control Row 1 (3)	28	102	258
	Control Row 2 (3)	50	161	159
	10 per cent. H.N.(A.) Row 1 (3)	9	34	350
	10 per cent. H.N.(A.) Row 2 (3)	11	60	497

Total number of trees: 44.

Table XIII.

Centre VIII.—Wilmington, Kent.

Date of application of washes: March 9th, 1929.

Date of final examination: September 18th, 1929.

Variety.	Treatment.	Percentage number of fruits marked by Capsid Bug. Per cent.	Weight of fruit marked by Capsid Bug. lb.	Weight of fruit unmarked by Capsid Bug. lb.
Lord Derby.	Control (6)	100	126	0
	10 per cent. S. (4)	83	200	12
	10 per cent. H.N.(B.) (6)	65	288	159
	10 per cent. H.N.(A.) (6)	97	447	40
Grenadier.	Control (6)	57		
	10 per cent. S. (6)	49		
	10 per cent. H.N.(B.) (6)	33		
	10 per cent. H.N.(A.) (6)	37		

Total number of trees: 144.

It will be observed that no weights were taken in connexion with the fruit of the variety "Grenadier" at this centre. For the count of the fruit of this variety thanks are due to the grower at this centre. It will be seen (Table V.) that, of the eight centres where the H.N.(A.) wash was applied, this centre was the only one where leaf damage by Capsid Bug exceeded "trace" on the sprayed trees. The actual reason for this deviation from the results obtained at all other centres is not yet apparent, and a further special investigation is therefore being conducted at this centre.

B.—*Caterpillars* (*Cheimatobia brumata* and allied species).

No special enumerations were made, but observations showed that at all centres really excellent control had been effected. The following table summarises the general results.

TABLE XIV.

Treatment.	Effect on Caterpillars.
12% S.	Complete control.
10% S.	Commercial control.
6% S.	Some reduction.
12% H.N.(B.)	Complete control.
10% H.N.(B.)	Complete control.
6% H.N.(B.)	Commercial control.
10% H.N.(A.)	Complete control.
8% H.N.(A.)	Complete control.
6% H.N.(A.)	Commercial control.

C.—*Aphis spp.* and *Psylla mali.*

Aphids were either absent, or only present in such small numbers on the control trees, that no definite enumerations could be made.

Psylla was present in some amount at several centres, and in all cases, all the washes at each strength employed, gave complete control.

2. *Plums.*

Of the three trials, two were situated at Evesham and one at Cheltenham, the numbers of trees being 25 (Victoria), 41 (Yellow Pershore) and 18 (mixed varieties), respectively—total 84. Only the "standard" and H.N.(B.) washes were used.

A.—*Aphis* (*Anuraphis helichrysi*).

At neither of the centres was there sufficient infestation to enable reliable conclusions to be drawn. The trials are therefore being repeated during the present year.

B.—*Caterpillars* (*Cheimatobia*, etc.)

The effect of the washes, when used at 6 per cent. concentration, was in accordance with the results given in Table XIV.

The washes used at 3 per cent. strength did not give any appreciable control.

3. *Black Currants.*

A.—Capsid Bugs (*P. rugicollis* and *L. pabulinus*).

B.—Aphids spp.

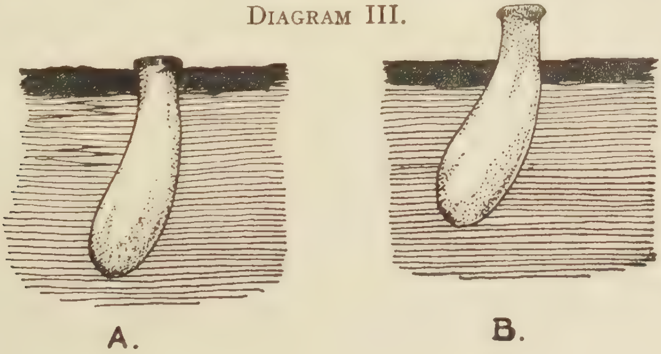
Trials were conducted at three centres, the results being shown in Table XV.

TABLE XV.

Centre.	Variety and total number of Bushes.	Treatment.	Capsid Bugs. Percentage of leaves marked.	Aphis.
I. (Newnham-on-Severn)	Baldwin (77)	Control	60	0
		10 per cent. H.N.(A.)	Trace	0
		6 per cent. H.N.(A.)	40	0
		6 per cent. H.N.(B.)	60	0
II. (Cheltenham)	Seabrook's Black, Edina and Blacksmith.	Control I.	50	0
		Control II.	60	0
		Control III.	80	0
		Control IV.	60	80
		10 per cent. H.N.(A.)	20	0
		3 per cent. H.N.(A.)	60	0
		10 per cent. H.N.(B.)	30	0
		3 per cent. H.N.(B.)	60	0
III. (Dunnington)	Baldwin (300)	Control I.	70	0
		Control II.	60	0
		10 per cent. S.	60	0
		10 per cent. H.N.(B.)	30	0
		10 per cent. H.N.(A.)	20	0

From the figures given above (Table XV.) it will be seen that, although the "high neutral" spray mixture has effected a considerable reduction in the infestation of Black Currants by Capsid Bugs, the control of this pest was, in this case, not so good as that obtained when these insects occurred on apples (see Table V.). The following considerations appear to the present authors to afford an explanation of this fact. Figure A., in Diagram III. represents the normal position of

DIAGRAM III.



the egg of a Capsid Bug as it is laid, embedded in the bark of the apple. Fig. B. represents the position in which a considerable proportion of the Capsid Bug's eggs are laid when deposited on black currants. Now, it appears evident, from the results given in this paper, that the eggs, when deposited on apple, may be killed by the stifling action of a film of oil over the small portion of the egg which protrudes from the bark. When, however, a considerable length of the egg protrudes and is exposed to the weather, as in the case of many of the eggs laid on currants, it can readily be conceived that it is much more difficult to ensure that the upper extremity of the egg is provided with the necessary, permanent, oily film.

LABORATORY-SCALE EGG-KILLING TRIALS.

With the endeavour to elucidate the manner in which insect eggs are prevented from hatching by means of winter washes a large number of trials have been conducted in the laboratory, eggs of the Small Winter Moth being treated with a large variety of products. The principal experiments are summarised in Table XVI. Each experiment was conducted in triplicate and the results obtained showed a good degree of concordance. All products were applied about six weeks before the eggs hatched, except where otherwise stated. In the two cases where the products to be tested were applied to the eggs shortly before the latter hatched the date at which it was deemed desirable to spray the eggs was ascertained in the following manner. All the eggs which had been sprayed, together with the batches of "controls" were kept in the Insectary at outside temperature. When it was thought that the period of hatching was approaching two of the controls were brought into a warmer room. As soon as these commenced to hatch some similar batches of unsprayed eggs which had been kept in the cool Insectary were treated with the desired products, just as the other batches had been treated nearly six weeks earlier. All the batches of eggs counted were kept in the Insectary under practically open air conditions until hatching was finished. The young larvæ were counted and removed daily from each batch of eggs as hatching proceeded.

The pure, crystalline solids the ovicidal powers of which were tested, namely Anthracene, Phenanthrene, Fluorene, Acenaphthene and Diphenyl Oxide are all constituents of the neutral tar-distillate and it was hoped, by examining the action of these compounds individually, to throw some light on the location of the toxic properties of the tar-distillate.

In the case of most of the solid substances (Anthracene, etc.) it was impossible to prepare emulsions. The respective compounds were therefore ground to a very fine powder and the latter suspended in a 2.5 per cent. aqueous solution of glue, to which 0.25 per cent. of the "wetting agent" Agral I had been added. No difficulty was then experienced in obtaining a uniform coating over the eggs of the substance which it was desired to test. Controls showed that the use of the glue-Agral I. mixture caused no significant lowering of the "hatch." In the case of Diphenyl Oxide it was found possible, as a check, to apply this compound both in the form of a suspension and as an emulsion prepared by means of Agral W.B. owing to the fact that the compound in question has a somewhat low melting point. It will be seen that both methods of application gave similar results and it may therefore be concluded that the results given by the other suspensions are not measurably affected by the method of application.

TABLE XVI.

Product tested. (Agral W.B. emulsions except where otherwise stated).	Concentration (% of actual product).	No. of eggs treated.	Approx. % hatch.
Controls	—	1,400	96
" High Neutral " Tar Oil	2.5	300	0
do. do.	5	306	0
" Low Neutral " do.	2.5	309	31
do. do.	5	297	3
" Low Neutral " Tar Oil (applied four days before hatching)	2.5	303	0
Asiatic Petroleum (High B.P.)	2.5	300	81
do. do.	5	307	75
Asiatic Petroleum (High B.P.) (applied four days before hatching)	2.5	301	5
Total Tar-Distillate	2.5	330	49
do. do.	5	300	5
" High Neutral " emulsified as commercial one-solution wash	2.5	302	3
do. do.	5	301	0
Neutral " Low Temperature Carbonisation " Tar, B.P. 290°-360°	2.5	321	1
do. do.	5	313	0
Pine-Wood Tar	2.5	299	82
do. do.	5	298	71
Neutral Tar-Distillate boiling *above* 360°	2.5	300	60
do. do.	5	315	23
Anthracene (Suspension)	2.5	301	82
do. do.	5	311	77
Phenanthrene do.	2.5	300	45
do. do.	5	319	33
Fluorene do.	2.5	309	27
do. do.	5	323	15
Acenaphthene do.	2.5	300	10
do. do.	5	316	4
Diphenyl Oxide do.	2.5	298	0.3
do. do.	5	301	0
do. (Emulsion)	2.5	310	1
do. do.	5	314	0
Paraffin Wax	2.5	331	81
do. do.	5	307	70
Paraffin Oil	2.5	300	75
do. do.	5	312	61
Heavy Medicinal Paraffin	2.5	301	0
do. do.	5	302	0

CONCLUSIONS.

The general inference that may be drawn from the foregoing results is that the killing of winter moth eggs is due chiefly to a " smothering " or " stifling " action caused by the deposition over the eggs of a uniform, oily film. Toxic action appears to play only a minor part. Thus, heavy medicinal paraffin, which can hardly be conceived as exerting a toxic action, is just as efficient an ovicide for winter moth eggs as is the " high neutral " tar oil. The low percentage kills obtained by the use of paraffin wax and the neutral tar product boiling above 360° C. may be attributed to the fact that the emulsions of neither of these products yielded, on drying, a uniform film, both of them giving a granular deposit of more or less solid particles. The fact that the low-boiling neutral constituents of the coal tar and also the Asiatic petroleum product were of much greater efficiency when applied to the eggs a few days before the latter would normally hatch than when they were applied six weeks before that time is evidently due to their relatively high volatility. Thus, when such substances are applied to the eggs early, the greater part of the product has evaporated before the arrival of the time at which the eggs become most susceptible to being killed, which appears to be the last few days before they hatch.

Some, at all events, of the pure, individual components of the neutral tar oil appear, however, to possess true toxic properties towards the winter moth eggs, this being notably so in the case of diphenyl oxide. The amount of the latter present in the neutral tar oil, however, is but very small, and the efficiency of the latter for ovicidal purposes evidently resides chiefly in its " stifling " action at all events as far as winter moth eggs are concerned.

In the case of eggs of the permanent apple aphis, it would appear that the toxic action of tar distillates plays an important part in their destruction. It has previously been ascertained by tests in these laboratories that heavy medicinal paraffin will not prevent the hatching of aphis eggs but it is well-known that aphis is readily controlled by a quite dilute tar wash. In other words aphis eggs cannot be stifled but they may readily be poisoned. In harmony with this conclusion one of us (L.N.S.) found some years ago, when conducting trials with emulsions of heavy lubricating oils, that the latter would not control aphis.

In this connexion it is of interest to recall some results which have been seen in the field by some of us during the past season. Last winter a number of growers employed a winter wash made from petroleum products for the purpose of controlling the Capsid Bug. When plantations which had been treated in this way were visited later in the year it was observed that a good control of Capsid and caterpillar had been effected, but the plantations showed considerable infestation with Aphis and Psylla.

SUMMARY.

The first essential for an efficient winter wash is that it should be prepared from a liquid capable of covering insect eggs on the trees with a uniform, varnish-like film which will not be removed by rain and will not evaporate appreciably before the time at which the eggs are due to hatch. The production of the desired uniform film depends, to some extent, on the method employed for the emulsification of the ovicidal material used.

The destruction of eggs of the Capsid Bugs and of the Winter Moth appears to depend chiefly on the stifling or smothering action of the oily covering which they receive, whilst a definite toxic action possessed by tar-distillates seems to be the chief factor in the destruction of eggs of Aphis and Psylla. Petroleum products do not exert this toxic action, but they can cause death of the eggs of certain insects by " smothering."

It has definitely been established, by trials during two seasons, that the " high neutral " tar-distillate wash devised at Long Ashton is capable of effecting a good control of the Apple Capsid Bug when used in 10 per cent. concentration. It will also control caterpillar at 6 per cent. and Aphis and Psylla at even lower concentrations. The commercial winter wash prepared from the same " high neutral " oil had a slightly lower order of efficiency, apparently due to the different emulsifier employed. It was, however, much superior to the older types of tar-wash made from the total distillate.

The reason for the comparative inefficiency, especially with respect to the control of Capsid Bug, of the older tar washes made from a total distillate lies in the following facts. Firstly, they contain a considerable proportion of relatively volatile material, which evaporates before the time at which the eggs are most readily killed. Secondly, they contain " tar acids " (and bases) which not only have a lower ovicidal power than have the neutral constituents of the distillate, but they are also easily washed out by rain from the material deposited on the eggs and, in being so removed, also take with them an appreciable quantity of the valuable neutral products, thus leaving the eggs covered with but an imperfect coating of oil.

ACKNOWLEDGMENT.

Plates II., III., IV., V., VI. are reproduced with the kind permission of the Controller of H.M. Stationery Office.

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(*Received* 16/1/30.)

PLATE I.

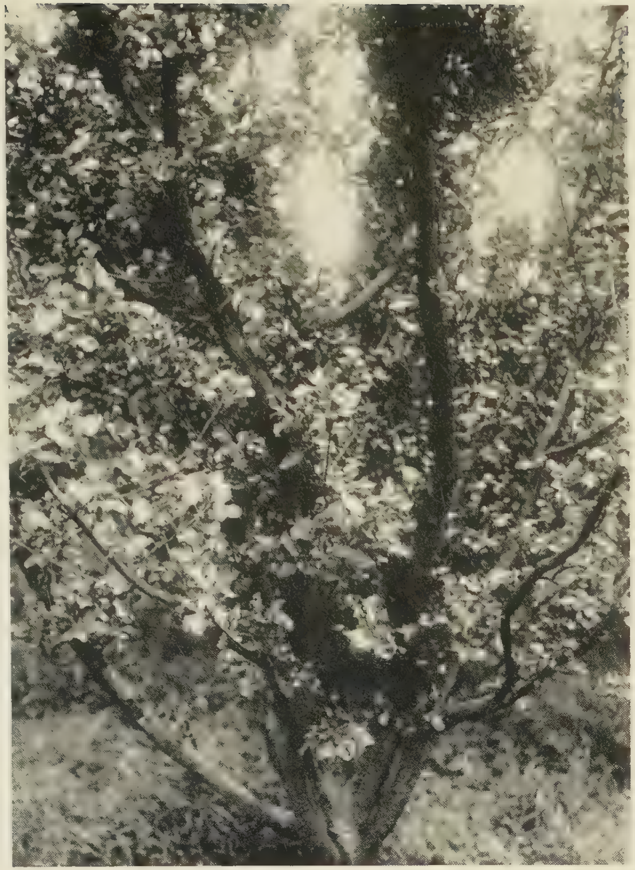

FIG. 1.

Control tree (variety King Edward VII.) at Centre IV. (Newnham, Glos.) showing severe caterpillar injury. Photographed July 5th, 1929.

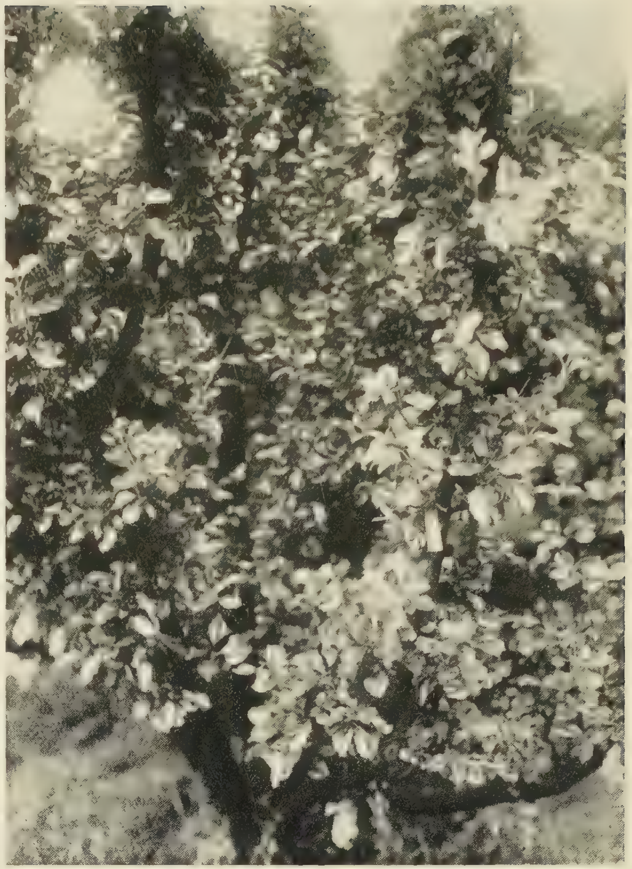

FIG. 2.

Adjoining tree of same variety as in Fig. 1 on plot sprayed with the Long Ashton wash at 6 per cent. strength. Note freedom from injury by caterpillars. Photographed July 5th, 1929.

PLATE II.

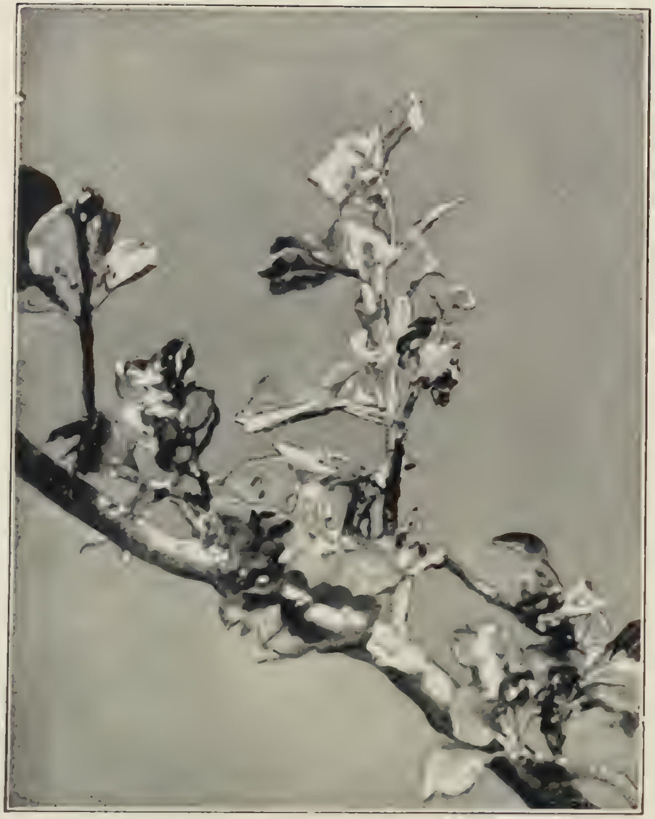

FIG. 1.

Portion of tree on Control Plot (variety King Edward) at Centre IV. (Newnham, Glos.). Showing severe caterpillar attack which, in conjunction with Capsid Bug damage, has resulted in poor shoot growth

Photographed July 5th, 1929.

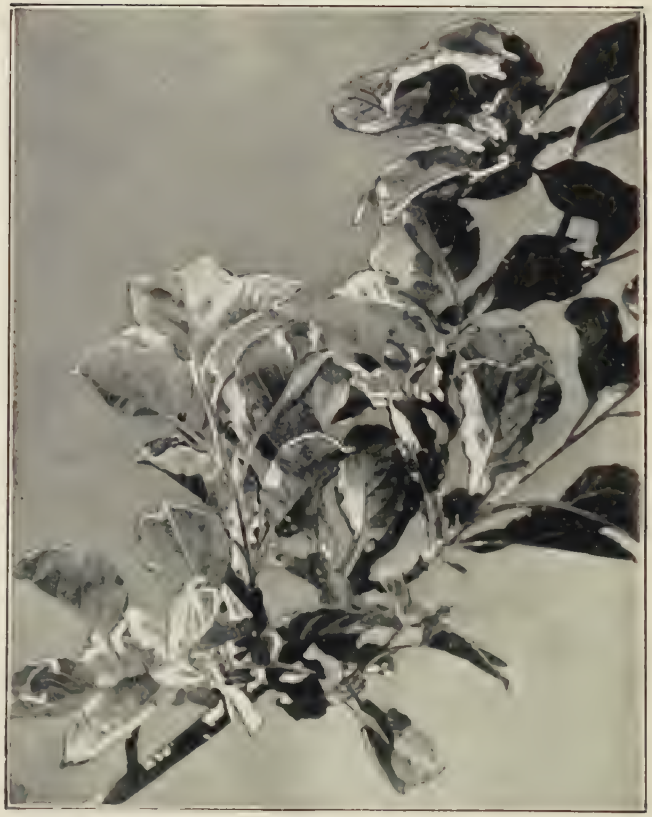

FIG. 2.

Portion of tree of same variety as in Fig. 1 on plot sprayed with the " High Neutral " wash (HNA) at 6 per cent. strength, showing vigorous shoot growth and freedom from injury. Photographed July 5th, 1929, at same Centre at Fig. 1.

PLATE III.

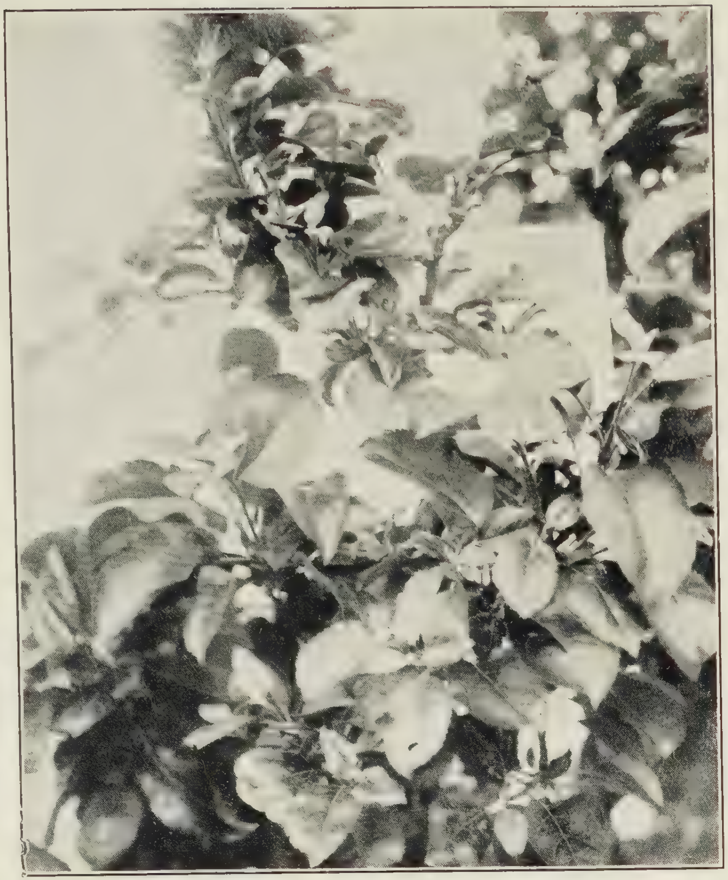

Fig. 1.

Early Victoria tree sprayed with the Long Ashton " High Neutral " wash (HNA) at 10 per cent. strength.
Photograph taken June 3rd, 1929, at Centre I. (Stawell, Somerset).
Note freedom from all pests, including Capsid Bug.

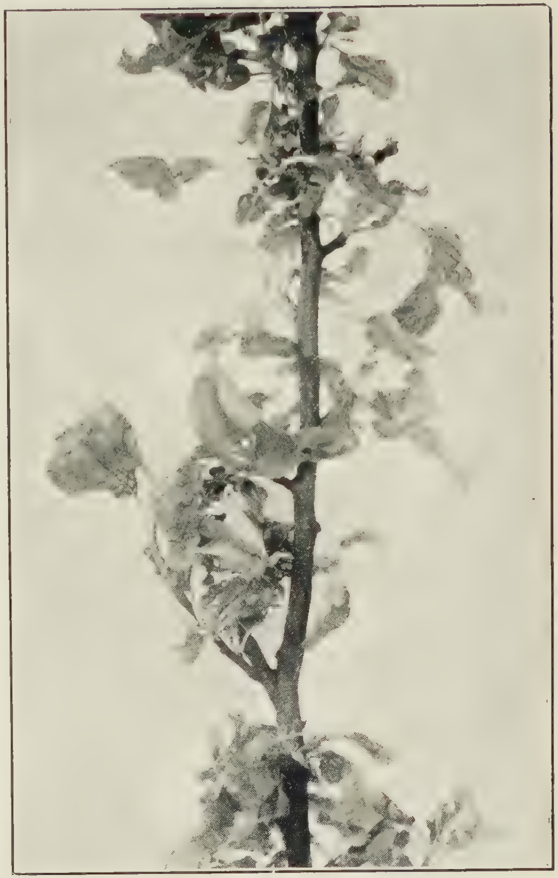

Fig. 2.

Unsprayed tree adjoining that shown in Fig. 1 at Centre I., photographed on same day.
Note severe caterpillar and Capsid injuries to foliage.
The blossom, it should be noted, was damaged by frost at this Centre.

PLATE IV.

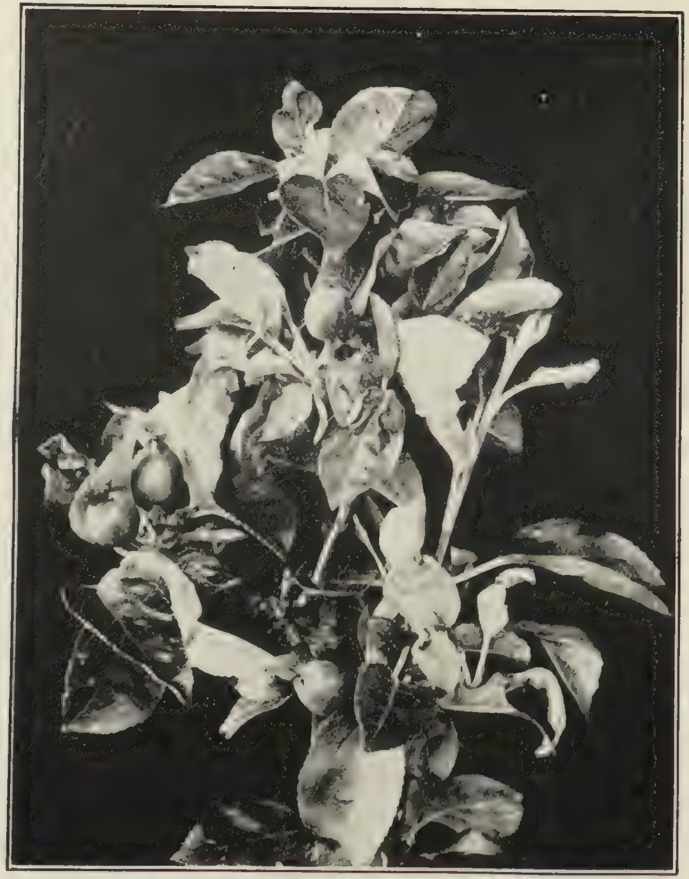

FIG. 1.

Sample branch of Prince's Pippin tree, at Centre III. (Hampton, Worcs.) from block of trees sprayed with the "High Neutral" wash (HNA) at 10 per cent. strength.
Photographed June 17th, 1929.
Note clean fruit and foliage

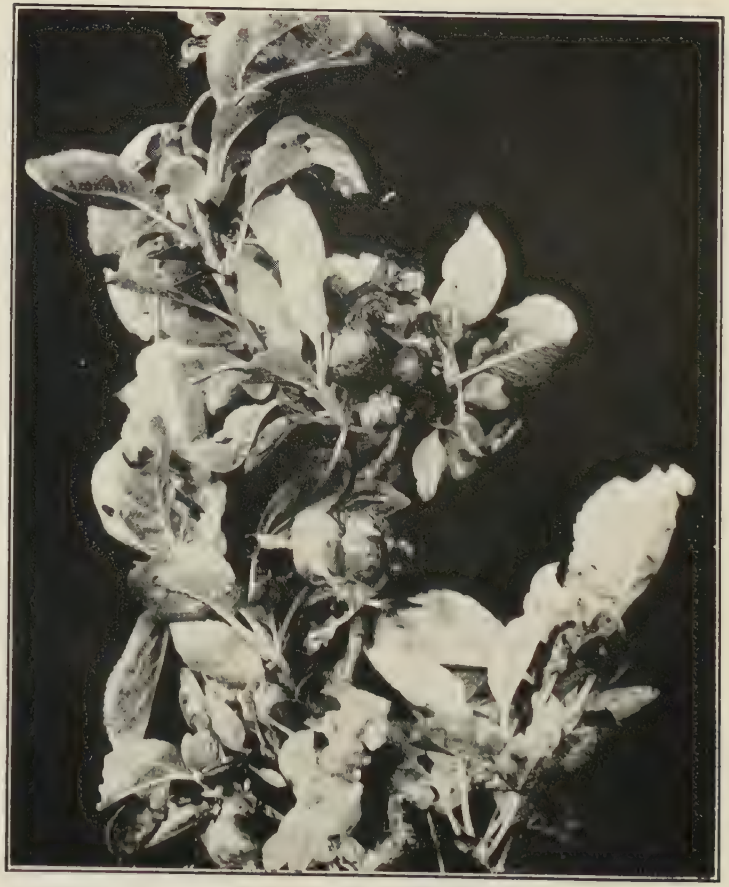

FIG. 2

Sample branch from tree, adjacent to that shown in Fig. 3, from a block of trees unsprayed.
Note severe caterpillar injury to leaves and Capsid bug damage to fruitlets.

PLATE V.

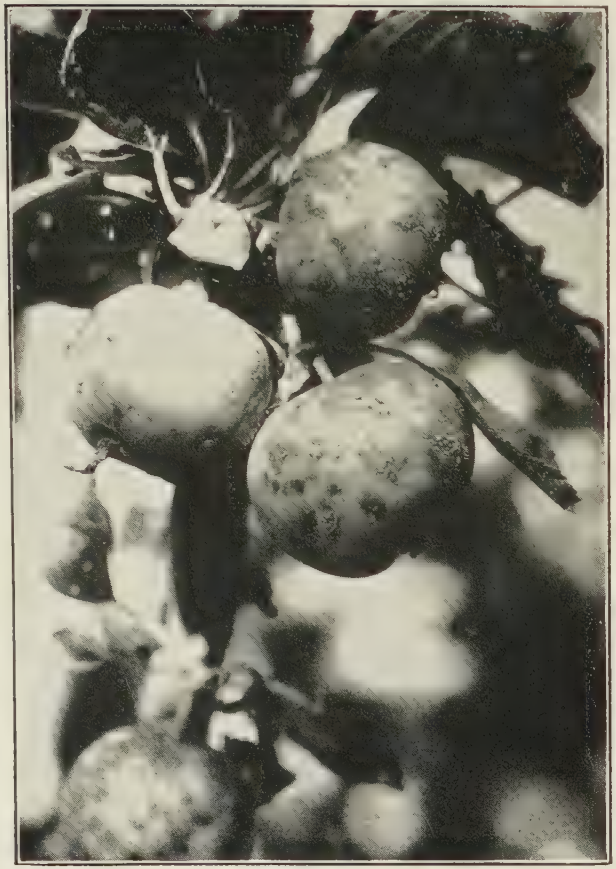

FIG. 1.

Prince's Pippin tree, unsprayed and adjoining that shown in Fig. 4. Note severe Capsid Bug injury to fruit. Photographed September 26th, 1929, at Centre III., Hampton, Worcs.

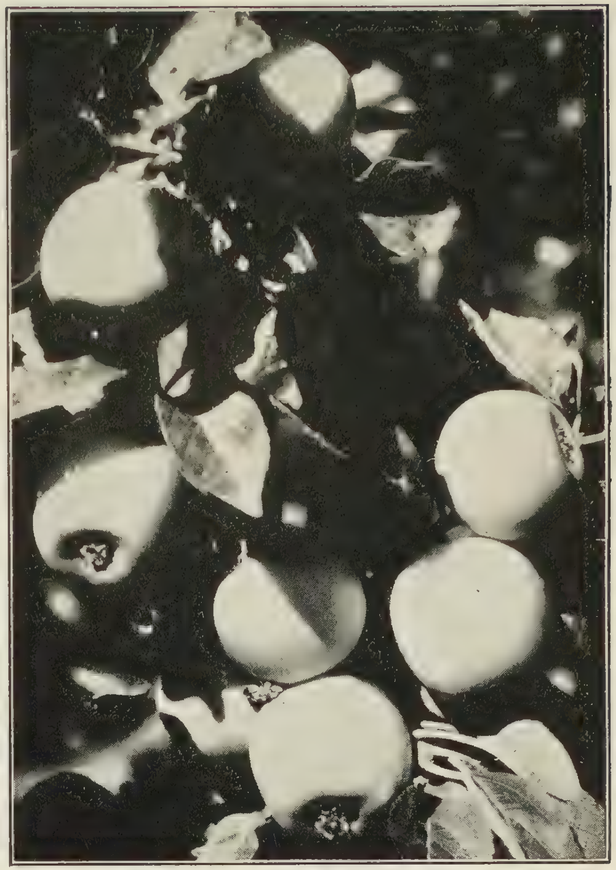

FIG. 2.

Prince's Pippin tree, sprayed with the "High Neutral" wash (HNA) at 10 per cent. strength, adjoining that shown in Fig. 3. Photographed on the same day.

PLATE VI.

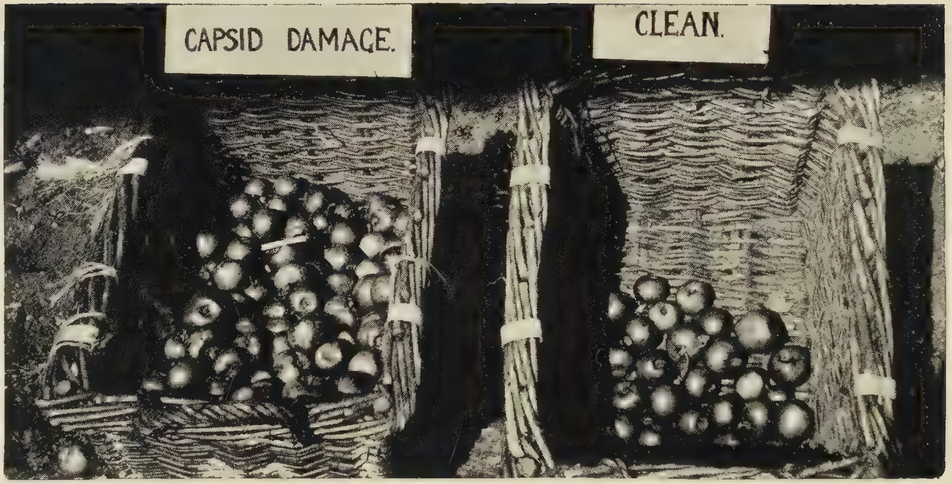

FIG. 1.

Total fruit picked from *two* Prince's Pippin trees unsprayed. The fruit has been graded as labelled.

Photograph taken at Centre III., Hampton, Worcs., September 20th, 1929.

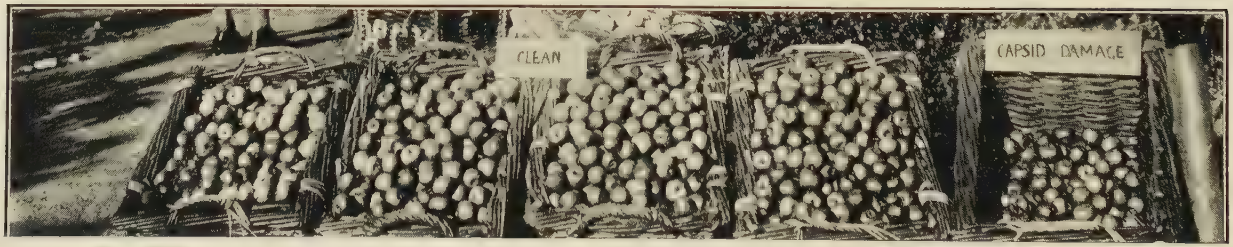

FIG. 2.

Total fruit picked from *four* Prince's Pippin trees, sprayed with the "High Neutral" wash (HNA) at 10 per cent. strength. The fruit has been graded as labelled.

Photographed at Centre III., Hampton, Worcs., September 20th, 1929.

A STUDY OF THE ANATOMICAL DEVELOPMENT OF THE APPLE AND SOME OBSERVATIONS ON THE "PECTIC CONSTITUENTS" OF THE CELL-WALLS.

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Horticultural Research Station, Long Ashton, Bristol.

THE work described in the following paper was undertaken as a part of a wider scheme of investigation on factors determining fruit quality now in progress at Long Ashton and aided by a grant from the Empire Marketing Board. Those responsible for the plan of that investigation have recognised that fruit quality ultimately is an expression of the conditions of nutrition, firstly, within the fruit tree as a whole and, secondly, within those portions of the tree immediately concerned with the production of the individual fruits. Those conditions as reflected in the fruit are accountable for differences in the chemical composition and physiological behaviour of the latter. To what extent those differences are associated with structural divergencies such, for example, as relative extent of development of individual tissues, epidermal character and the nature and distribution of the vascular supply has not been investigated in detail hitherto. Before progress in the solution of such problems can be made considerably more knowledge of the histological structure and developmental anatomy of the fruit is required and the object of the present study is to furnish more information on those subjects in the case of the apple. Incidentally such knowledge may help to explain some of the peculiarities bound up with the keeping qualities of apples and to throw light on some of the problems of fruit storage.

Previous work on the apple of a morphological nature is confined to that of E. J. Kraus in America and Zschokke in Switzerland. Kraus was chiefly concerned in determining the nature of the different tissues of a pome fruit. Little definite information about the development of the apple is given beyond the statement that the increase in the number of cells of the flesh is due mainly to a cambial region situated in the region of the main ring of vascular bundles. Zschokke's paper deals almost entirely with the structure of the skin of the apple together with some details about the development of lenticels.

SCOPE AND METHODS OF INVESTIGATION.

The present investigation comprised a study of the structure of apple fruits at all stages of development from the flower to the mature fruit. No detailed examination of the associated chemical changes was attempted, but it was considered desirable to include some observations on the pectic changes of the cell walls as discernible by microscopic examination after appropriate staining in view of their relation to the ripening processes of the fruit and its keeping quality.

The following varieties were used: Wagener, Stirling Castle, Court Pendu Plat, Edward VII., Medaille d'Or, Sweet Alford, Lane's Prince Albert.

These varieties were selected as representative of the main classes of apples, Stirling Castle, Edward VII. and Lane's Prince Albert are culinary sorts of relatively high acidity. Wagener and Court Pendu Plat represent the dessert class, with medium acidity. Sweet Alford is a cider variety of the sweet class, characterised by low acidity and low tannin content. Medaille d'Or is another cider variety, in this instance of the bittersweet class, distinguished by low acidity and low tannin content.

The stages of development from flower to fruit and the epidermal characteristics of different varieties of apples were studied by means of serial microtomed preparations. The earliest stages cut were those of the ovary of the fully formed flower. The usual fixatives (Chrome Acetic, Fleming's Strong Solution, Formalin Alcohol) were used with satisfactory results. Transverse and longitudinal sections were prepared and Heidenhain's Iron-Alum Hæmatoxylin was used to stain the early stages and Cotton Red with Picric Aniline Blue as counterstain for the mature stages.

OBSERVATIONS ON DEVELOPMENTAL ANATOMY.

A transverse section through such an ovary showed a well-defined epidermis, a large proportion of the cells of which were elongated to form numerous projecting hairs. Between this and the ring of vascular bundles was a region of undifferentiated cortical cells. The ring of vascular bundles was the only indication of the position of the future line between the cortex (outer flesh) and the pith or inner flesh in which the carpels were embedded. At the earliest stages examined (25. v. 27) the ovary was made up of uniform cells throughout, with the exception of the vascular bundles which were always a prominent feature of any section. The cells of the epidermis were elongated in a radial direction and the continuity of this layer was unbroken by stomata in the early meristematic stages. (Text Fig. 1.)

The vascular supply of the ovary was made up of two systems, an outer and an inner system, which united at the base of the apple and became continuous with the vascular supply of the stalk. The outer system was the largest of the two and it provided the conducting system for the whole of the cortex, i.e., the main part of the flesh of the mature apple. The inner vascular system ran up the placentæ and supplied branches to the ovules and also some which kept in close contact with the carpel walls (i.e., the core). When the placentæ became merged into the style, the inner vascular supply continued up this to the stigmas.

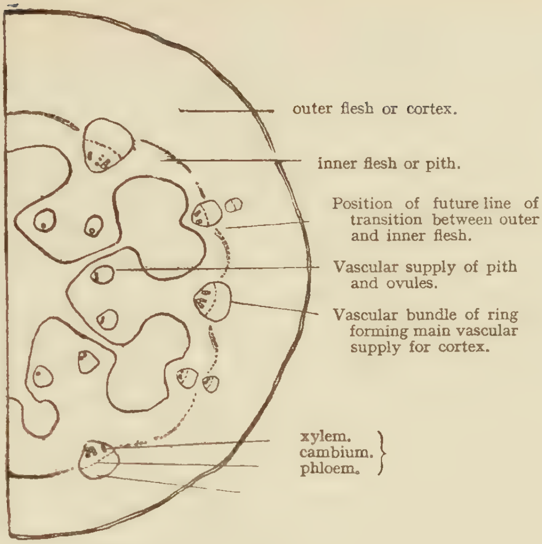
outer flesh or cortex.
inner flesh or pith.
Position of future line of transition between outer and inner flesh.
Vascular supply of pith and ovules.
Vascular bundle of ring forming main vascular supply for cortex.
xylem.
cambium.
phloem.

FIG. 1.

T. S. Wagener to show distribution of tissues at an early stage.

At the apex of the apple, where the style became free from the ovary (see Text Fig. 2) a ring of small cells with comparatively thick walls was differentiated. These became very conspicuous in later stages owing to heavily stained contents and thick walls which were in contact with the thin walled cells forming the outer part of the cortex in this region. Cork formation occurred on the inner free surface of this small-celled layer and this became continuous with that formed about a quarter of the way up the style after fertilisation had taken place.

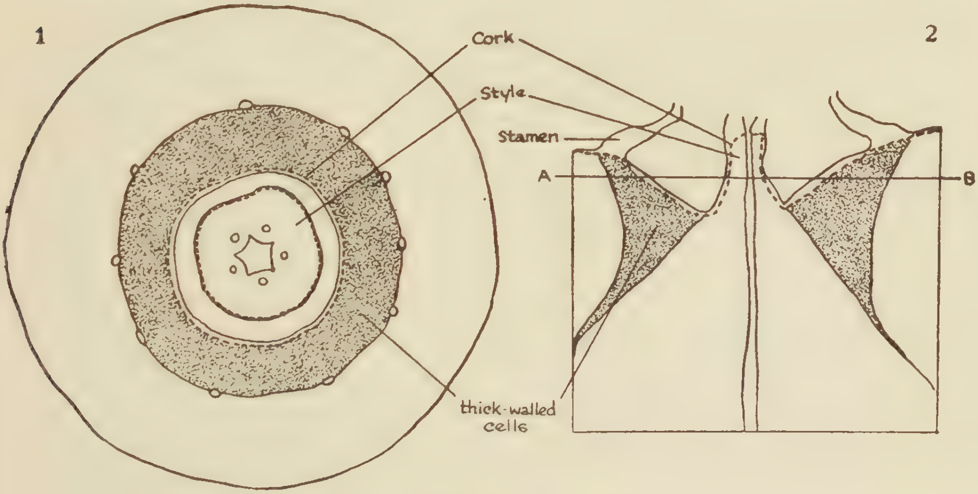
1
2
Cork
Style
Stamen
A
B
thick-walled cells

FIG. 2.

1. Transverse section of apex of apple at level A.B.
2. Longitudinal section of apex of apple.

Post-meristematic Stage.—Differentiation Changes.

The meristematic stage of the apple was of short duration and by the end of May (Wagener, 1927) a certain amount of differentiation was noticeable. The line separating the pith from the cortex was still hardly visible but throughout both these regions, the cells had begun to vacuolate although the nuclei of the cells still remained prominent. The commencement of vacuolation was accompanied by a considerable increase in the size of the ovary showing that the fruit had set. The vacuolation was found to have taken place to a much greater extent in some groups of cells than in others and consequently had produced the effect of groups of thick walled cells amongst thinner walled cells owing to the pushing back of the cell contents against the wall. These groups of vacuolated cells occurred quite irregularly throughout the cortex.

At this stage, the sub-epidermal cells were small and slightly elongated in a tangential direction. They had slightly thicker walls than those of the cortex.

The period between the setting of the fruit and its maturity was characterised by the gradual increase in the amount of the flesh and this was found to have been brought about principally by the rapid vacuolation and increase in size of the cortical cells but also by means of cell divisions which took place in these vacuolated cells.

The epidermis remained meristematic to a late stage which enabled it to keep pace with this increase in size. Finally the epidermal cells themselves vacuolated and elongated in a tangential direction.

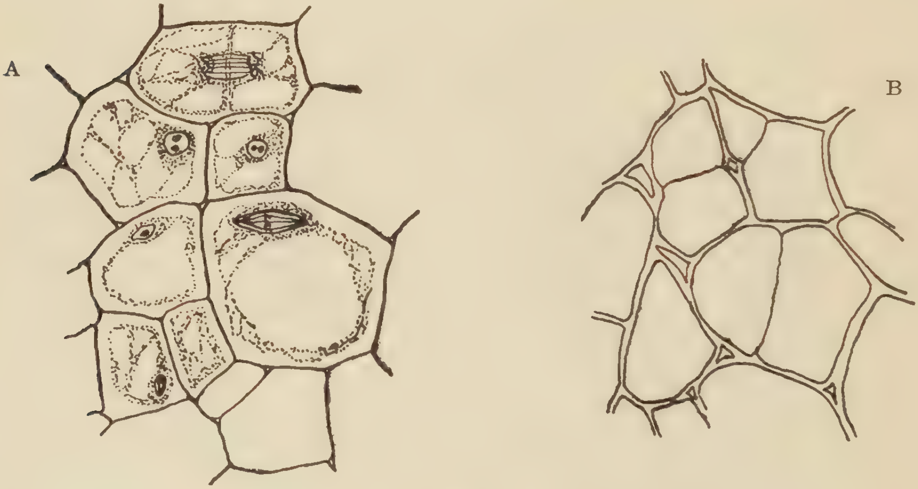

Fig. 3.

A. Wagener. Dividing nucleus in vacuolated cell.
B. Wagener. Typical cells of the ground tissue after divisions in vacuolated cells.

The sub-epidermal cells, after the first rapid swelling of the apple gradually became more thick-walled in spite of the rapid increase in the size of the tissues within and the consequent pressure on the external layers.

The synthetic activities of this tissue must be maintained at a high rate to produce the deposits of cellulose and pectin which formed the thick walled sub-epidermal cells of some varieties in their mature stages. The cell walls were probably of a very gelatinous nature because intercellular spaces were hardly detectable until the later stages when these cells were becoming stretched in a tangential direction. That this region of the apple was capable of considerable activity was shown by the frequent occurrence of cork formation below the hair bases and in the sub-epidermal cells beyond.

Nuclear division in the vacuolated cells of the cortex produced cells in which a thin cross wall was laid down across the thicker walled parent cell. Nuclei in the actual process of division were observed fairly frequently. These dividing nuclei were nearly always surrounded by dense protoplasm.

Judging by the frequency of the occurrence of these cells, this method of cell-formation was probably an important factor in the increase in the size of the apple in its later stages.

The main vascular bundles too had contributed to this increase in size, for the cambium was very active cutting off both phloem and parenchyma towards the outside of the vascular bundles. The latter, i.e., the parenchyma, became part of the ground tissue on the addition of younger elements within. Most of the main vascular bundles, except in fully matured apples, showed on the outside large parenchyma cells which were mixed up with the somewhat crushed remains of the old phloem elements. In the mature apples, the older phloem elements had been crushed out of existence.

STOMATA.

Stomata could not be found in any of the varieties examined until the cells of the cortex were showing the first signs of vacuolation and intercellular spaces were forming in this region. An account of their development will be given when the rest of the epidermal structures are described.

INTERCELLULAR SPACES.

Intercellular spaces were a marked feature in any section through the flesh of the apple but they were very minute in the earliest stages and only began to be really noticeable when the cells began to vacuolate. The possibility that the intercellular spaces might at first contain water was tested to a certain extent by means of sections cut and mounted in glycerine after the apple had been cut off the tree under water. The intercellular spaces which contained air showed up black in the sections. A fairly large proportion of the intercellular spaces in the cortex were found to contain liquid although some air-filled spaces were always present. The intercellular spaces in the sub-epidermis however remained free from air until some time after the formation of stomata.

No noticeable differences in cell size could be seen in the developmental stages in the varieties examined.

After the vacuolation of the cells had been going on gradually for some time, the cells themselves began to increase rapidly in size. This took place some time during June and depended upon whether the variety ripened early or late. This increase in the size of the cells went on more slowly during July and August and in the last stages before the apple was picked any increase in volume of the apple appeared to be due mostly to an enlargement of the air-spaces only. The continued increase in the size of the apple would be made possible by the continuation of cell-division in the sub-epidermal cells after it had ceased in the inner layers, followed by an extension of the cell wall in the former region.

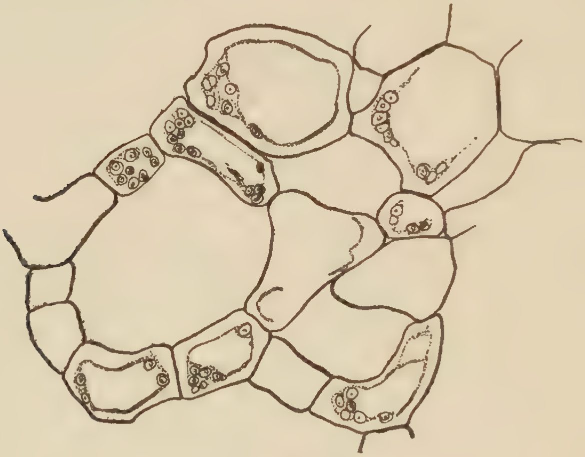

FIG. 4.
Sweet Alford, 22 viii. 27, showing cells of cortex with intercellular spaces.

TRANSITION LINE BETWEEN CORTEX AND PITH.

The line of transition between the cortex and the pith was clearly visible in the later stages of growth. Kraus (6 and 7) considered that this line marked the position of a cambial layer to the activity of which the increase in size of the apple was due. No sign of any cambial layer was found in this region in any of of the varieties examined.

The main vascular bundles ran up the apple in this transition region and formed a series of comparatively rigid lines surrounding the central core. The more rapid swelling of the cells of the outer flesh beyond the vascular bundles (limited by the stretching capacity of the epidermis) where they abutted on those of the pith (the size of the cells of which are limited by the stretching capacity of the vascular bundles and the core) would produce a definite zone where the cells which must be subjected to different strains changed from one type into the other. Also this transition line was not detectable until the apple was undergoing its most rapid change in size and all meristematic activity was over.

SUMMARY.

The stages in the development of the apple could be summarised as follows :

1. In the flower bud, the apple consisted mainly of a mass of meristematic cells through which vascular bundles were differentiating.

2. During the flowering and setting stages of the fruit, this meristematic cell-division ceased and was replaced by division in vacuolating cells.

3. After the fruit had set, growth was characterised firstly by vacuolation of the cells, later by a rapid increase in the size of the cells and finally by a rapid development of the intercellular spaces. Divisions continued to a later stage in the sub-epidermal cells and later still in the epidermal cells themselves. This enables the epidermis to keep pace with the increase in size of the internal tissues.

4. Increase in size of the cells and vacuolation accompanied by a large development of air-spaces in the ground tissue continued until the apple was mature.

THE EPIDERMAL STRUCTURE OF THE APPLE.

INTRODUCTION.

The epidermis of the apple has been investigated by previous workers, the most important paper on the subject being that of Zschokke (11). He found that stomata were present in apples and that they were evenly distributed over the whole surface in the youngest stages. He noted a preponderance of stomata at the apex in the later stages which he held to be due to the increased tangential stretching of the lower half of the apple. In the species he examined, cork formation occurred below the stomata during the latter part of the season and it was this corky tissue that formed the definite spots seen on the skin of the apple which is so characteristic of some varieties. In some cases, the stomata might split without any subsequent cork formation and the walls of the outer cells dried back to the underlying tissues. No new stomata were laid down after the first swelling of the ovary. The presence of epidermal hairs and their connection with lenticel formation was also mentioned together with the fact that "lenticel" formation in these cases was not like that of a typical lenticel but he considered that they were comparable in function and in origin. The formation of cork in russet apples was found to commence about 6-8 weeks after flowering and he noted that if the fruit was shaded early the skin was thinner than that of unshaded fruit and no russeting occurred. The paper included some observations on the resistance of fruit towards fungi. He concluded that the mechanical protection afforded by a thick-walled epidermis and cuticle against the entrance of fungi was rendered more or less useless on account of the numerous openings present in the skin. He considered that any resistance shown by the fruit was due to the presence of chemical substances and not to its structure.

Kidd and Beaumont (5) when studying fungal invasion of apples in storage made a special study of invasion through the lenticels. They traced the formation of lenticels back to the epidermal hairs or stomata and they considered that these gaps in the epidermis only functioned as lenticels when cork-formation occurred below. They also commented upon the small number of stomata in a mature apple.

Development of Stomata and Lenticels.

A study of the development of the stomata during the present investigation showed that they were formed when the vacuolation of the ground tissue had begun. The presence of an extra large epidermal cell was the first sign that stoma formation was beginning. This cell was always situated above a very small intercellular space (Text Fig. 5A) and no stages could be found of the latter without an enlarged epidermal cell above. The stomatal mother-cell divided to form the two guard-cells, which later became separated by a minute passage way leading into the intercellular space below. The cells surrounding this space stained heavily and had dense contents. They evidently continued to divide and thus led to the enlargement of the intercellular space below the stomata and the final separation of the guard cells. In this condition, the stoma may have functioned for a short time as a channel for the exchange of air. The formation of the stoma was evidently rapid and it took place before the active swelling of the cells of the cortex.

Transition stages between lenticels and stomata were difficult to find, but stages showing the guard cells of the stoma pressed against each other occurred (doubtless owing to the continued activity of the epidermis) and in a few of these cases cork formation had evidently begun below the stoma, such a stage being shown in Text Fig. 5E. Since stomata on mature apples were extraordinarily difficult to find, lenticel formation must occur in nearly every case without leaving any trace of the stoma whatever.

Counts were made of the number of stomata in each section of a series through half an apple so as to obtain additional data as to the number formed and their

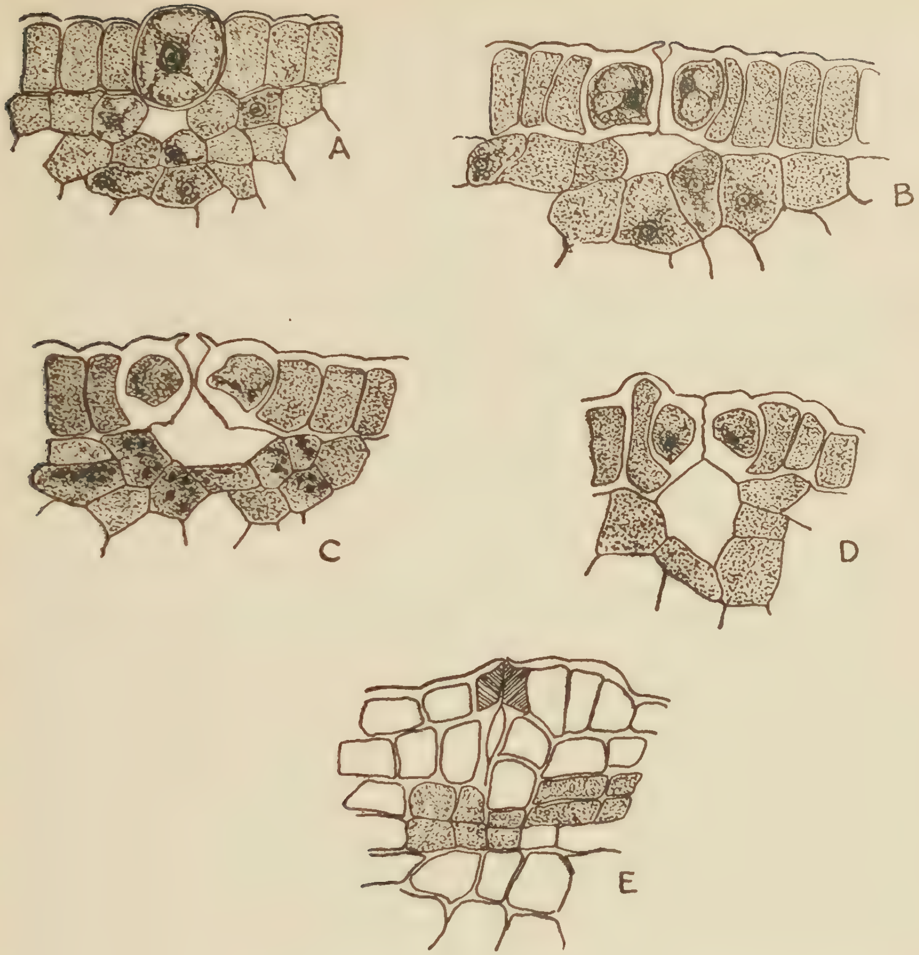

FIG. 5.

A—D. Stages in formation of stomate in Court Pendu Plat.
E. Cork formation below stomate in Lane's Prince Albert.

distribution. The result of these counts, which are given below in Table I., showed that the number of stomata and their distribution might vary considerably in some varieties. The two counts made in the case of " Stirling Castle" showed that a considerable increase in the number of stomata could occur during June. The high number of stomata found in Court Pendu Plat in early June suggests that no further additions would be made during the month. The following tentative conclusions could also be drawn.

1. When the stomata were formed rather late in the development of the apple few were formed and these mostly towards the calyx end.

2. When they were formed early in the development of the apple, they were formed over the whole surface and the subsequent swelling of the apple resulted in the apparent concentration of the stomata at the apical end.

Table I.

Number of Stomata in serial sections through half an Apple.

Wagener.		Stirling Castle.				Court Pendu Plat.	
9.vi.27.		9.vi.27.		16.vi.27.		9.vi.27.	
Apex of Apple ..	41	Apex of Apple ..	10	Apex of Apple ..	20	Apex of Apple ..	67
Central Region ..	15	Central Region ..	9	Central Region	20	Central Region ..	72
Base	5	Base	1	Base	17	Base	34
Total per half apple =	61	Total per half apple =	20	Total per half apple =	57	Total per half apple =	173

Significance of Hairs.

The epidermis of all varieties of apples examined bore hairs which grew out directly from a single cell to a considerable length and finally developed a comparatively thick wall. When the apple began to increase rapidly in size, these hairs became more isolated from each other and in time became broken off near the base. When sections of the epidermis at this stage were stained with Sudan III. in glycerine and alcohol, the base of the hair was found to be impregnated with fatty substances which gradually extended into the lower tangential wall. The bases of these broken-off hairs must have provided a suitable foothold for fungal spores but when a suberised layer was present at the base of the hair, fungi would probably find difficulty in penetrating without some previous injury in this region.

These hair bases evidently represented weak places on the surface of the apple for any crack in the skin nearly always began in this region. The breaking off of the hair would mean the collapse of a turgid cell in a stretched epidermis

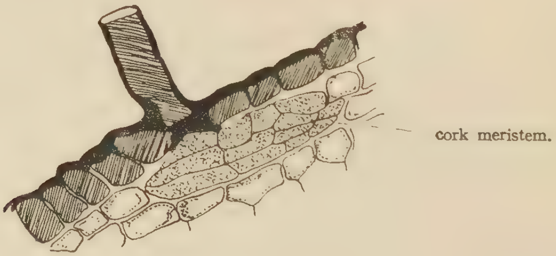

Fig. 6.
Sweet Alford showing early formation of cork below hair.

and this might be sufficient to start a crack in the cuticle which would continue to develop if any pressure was exerted upon it from the inside.

In some varieties, cork formation occurred below the base of the hair soon after the breaking off of the part projecting from the epidermis. In the majority of cases, however, this did not occur until the cells of the hair base had begun to show signs of drying back. The upper layer of cells dried back first. This was subsequently followed by cork formation which might extend for some distance through the sub-epidermis.

Both these examples might occur in the same apple, but the variety Medaille d'Or was one in which cork formation nearly always seemed to take place at an early stage.

Lenticels which are formed after the rupture of the base of the hair at a comparatively late stage in the development of the apple must increase any liability to fungal infection. In this connection, it is interesting to note that Kidd and Beaumont found that 75 per cent. of the inoculations above the lenticels of stored apples produced rot subsequently. The resistance of the remaining 25 per cent. might have been due to the much more effective cork barrier which could be formed if it was laid down before the rupture of the hair bases had occurred. Kidd and Beaumont distinguished between open lenticels and blocked lenticels and even in the case of the former there was a 15 per cent. failure to penetrate. No differences in cork formation were noted, but the open lenticel would probably be one in which the drying back of the exposed cells had occurred without much cork formation below. Probably the lenticels in this case were too open to allow the spores to germinate for other experiments led to the conclusion " that failure to invade under natural conditions in storage is due in part to lack of available moisture for the fungus outside the host and in part to the unsuitable quality and insufficient concentration of the exosmosed nutrient."

RUSSETING AND CRACKING.

The skin of all varieties of apples has to withstand a certain amount of strain caused by the developing tissues within, and after certain types of weather this strain is increased so rapidly that cracks occur which have no reference to the bases of hairs or to the lenticels. Such cracks were frequently found during 1927 and 1928, especially in Cox's Orange Pippin and in Allington Pippin. These cracks were healed by the formation of cork and marked differences were noticed in its extent and regularity in these two varieties. Cork formation in Cox's Orange Pippin was very irregular and suberisation of the cells occurred in only one or two layers. In Allington Pippin, however, suberisation was comparatively regular and generally extended to at least three rows of cork cells.

Extensive cracking occurred in the summer of 1928 in the varieties James Grieve and Beauty of Bath as early as the beginning of June. Most of the cracks were formed on the sunny side of the apple. A long dry, cold period when the fruit was setting had been followed by a warm rainy period when the apple was ready to swell. The cold period had produced a comparatively thick and unelastic type of cuticle especially on the exposed side of the apple with the result that the epidermis was unable to resist the rapid swelling of the cells within and had consequently cracked. These cracks had been healed by cork formation of a rather irregular nature with only a light suberin deposit on the cell-walls.

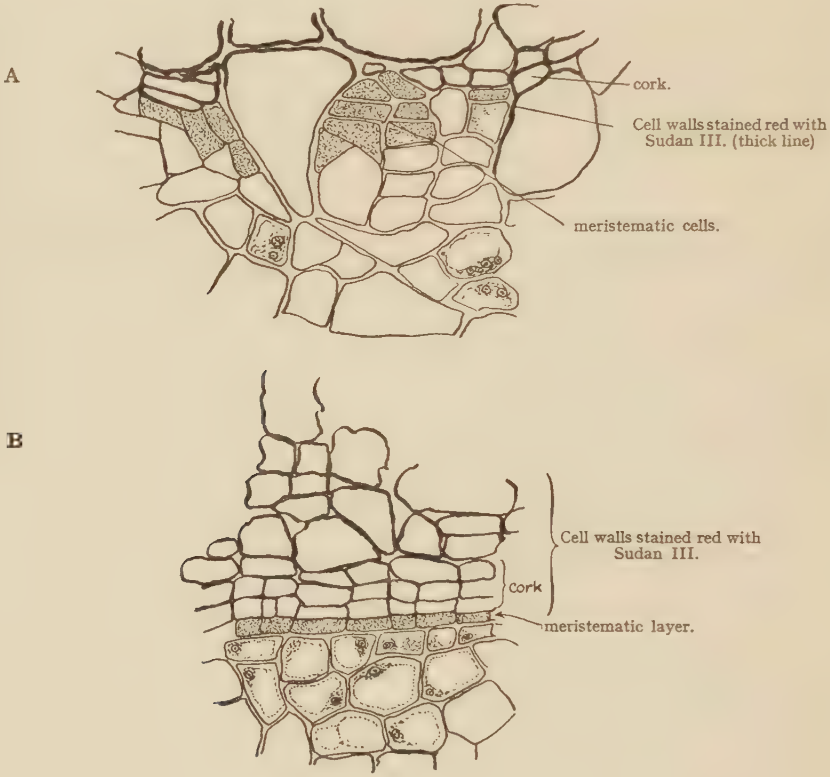
A
cork.
Cell walls stained red with Sudan III. (thick line)
meristematic cells.
B
Cell walls stained red with Sudan III.
Cork
meristematic layer.

Fig. 7.
A. Cork formation in Cox's Orange Pippin.
B. Cork formation in Allington Pippin.

Cox's Orange Pippin is one of the commonest varieties to show the condition known as russeting which is closely bound up with cork-formation. The extent of the russeting varies considerably from season to season and some varieties in this country never become russeted although they may be exposed to conditions similar to those producing russeting in another variety.

Sections through a russeted skin showed on the outside several layers of dead cells above a continuous layer of cork and the meristem layer from which it was derived. (See Text Fig. 8.)

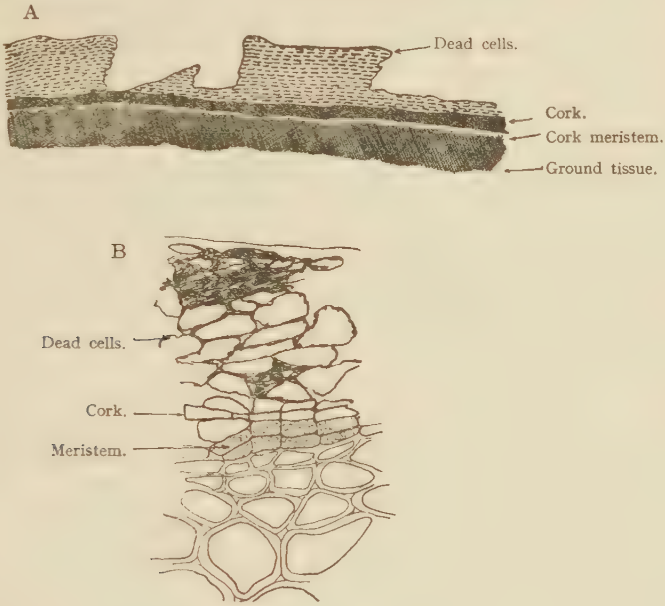

FIG. 8.

Russeting in Cox's Orange Pippin.

A. Diagram of transverse section through russeted skin.
B. Same under high power.

The normal unrusseted part of the skin had a thick and rather irregular cuticle and epidermal layer, a type which was not plastic enough to resist the internal strains put upon it and this rather rigid skin had been replaced by cork-formation over a large part of the outer surface of the apple.

CUTICLE CHARACTERISTICS.

The cuticle deposited on the mature epidermal cells was found to vary very considerably in the varieties examined. The cuticle might be deposited on the tangential wall so that it touched the apex only of the radial wall. In other cases, the deposit extended throughout the length of the radial wall or even completely surrounded the cell. The first type of deposit would produce an epidermis more capable of extension than the second or the third type. Bramley's Seedling was an example of the first type of cuticle (i.e., cuticle deposited to the top of the radial walls only) and it is not a variety of apple that cracks easily. Cox's Orange Pippin, in which cracks and russeting often occur and Newton Wonder have suberin deposits which often extended round the lower tangential walls. These differences in the deposition of the cuticle and the correlated differences in the shape and size of the epidermal cells themselves are shown in Text Fig. 9.

The extent of the correlation of structure with the keeping qualities and susceptibility to disease of apples cannot yet be estimated fully. The most important feature in this connection appears to be the ability of a given variety to form regular layers of cork quickly and also the stage at which lenticel formation occurs, i.e., whether cork formation occurs before or after the breaking off of the major portion of the hair. The structure of the normal epidermis and cuticle too must be of importance, for it determines very largely whether a given variety will give equally good results in the varied types of weather to which

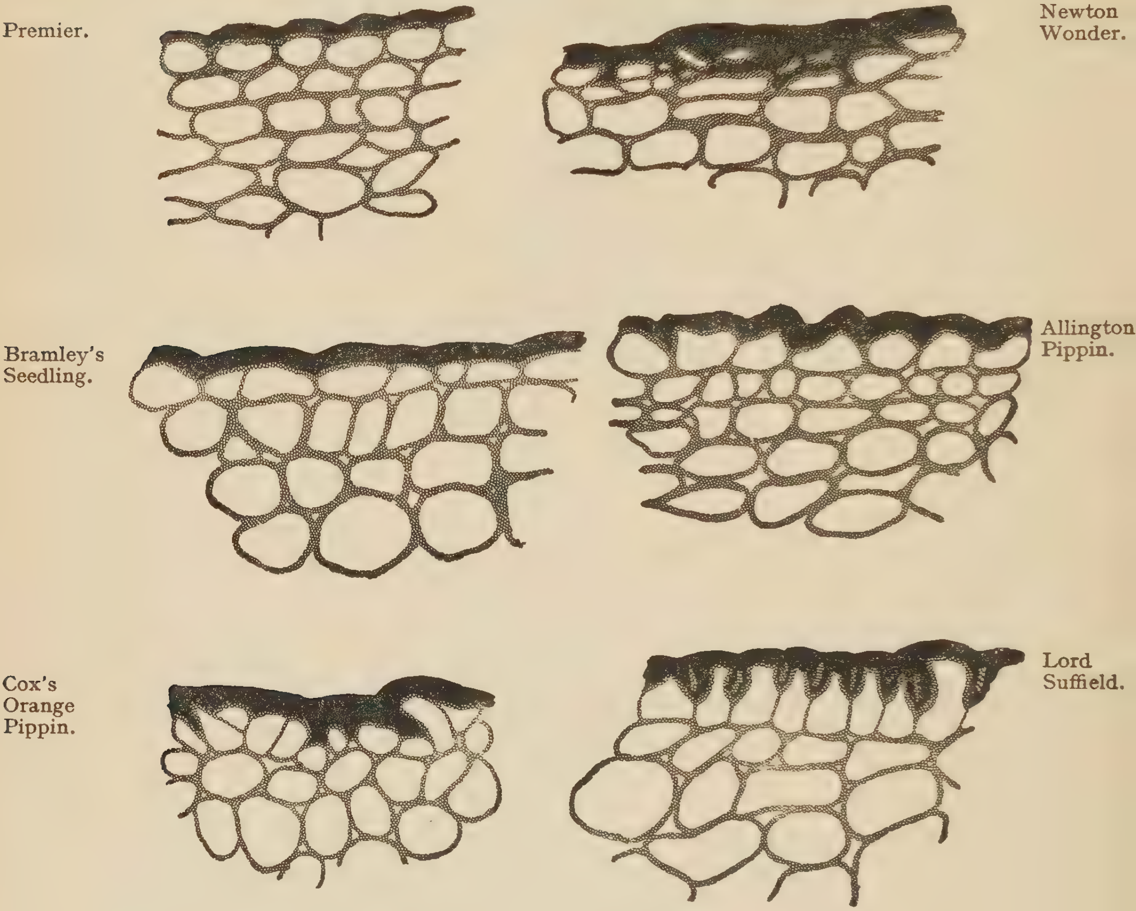
Premier.
Newton Wonder.
Bramley's Seedling.
Allington Pippin.
Cox's Orange Pippin.
Lord Suffield.

FIG. 9.

Transverse sections of skins of several varieties of apples.

they may be subjected in this country during a normal season. Further work along these lines would be useful as there is no doubt that the range of epidermal structure is very large in apples and very little is known as to the effects of external conditions on these varied types of skin.

THE "PECTIC CONSTITUENTS" OF THE CELL-WALLS.

The chemical work done during this investigation was confined to a series of micro-chemical experiments on the pectin constituents of the cell-wall on the same lines as those of Carré and Horne (4). As a result of a series of experiments they concluded that the pectin of apples was present in three different forms. It might be in the cell-wall in the earliest stages as protopectin, in which case it was insoluble in water but rendered soluble by treatment with hydrochloric acid. Later this was transformed into soluble pectin (i.e., soluble in water). The third form was middle lamella pectin which was supposed to be a complex containing pectin acid or a salt of the acid.

The experimental evidence on which the presence of protopectin was based was that the pectin could not be extracted by water only, the residue being dissolved out in hydrochloric acid. Tutin (10) however considers that it is possible to extract all the pectin by treatment with water if only the material was ground fine enough, even in the case of unripe apples in which the tissues are very resistant. Carré and Horne found that in stored apples the amount of protopectin fluctuated and less protopectin was found in soft varieties than in hard varieties. The difference in the resistance to any disintegrating process in these two types would explain these fluctuations and Tutin holds that there is no necessity to assume the formation of protopectin before that of soluble pectin.

Carré and Horne's observations suggested that the pectin itself was re-arranged at an early stage after its deposition on the cell-wall and pectin structures were then elaborated of a definite shape. The first signs of differentiation was a stronger reaction to Ruthenium Red in that part of the wall abutting on an intercellular space. After this, discs of pectin were formed in the walls of contact and crescents near the boundary of these walls. Bands of pectin were also noted in the walls and on the free walls of the cells (i.e., walls abutting on an intercellular space) the pectin might take the form of papillæ and globules.

The above observations were made on Bramley's Seedling. During the present investigation, other varieties besides Bramley's Seedling were used for this part of the work.

Ruthenium red was used as the stain for pectin, but it was found that comparatively little is known about the action of this stain beyond the fact that it is taken up by cell-walls in which pectin is known to be present by other chemical methods. Pectin itself when isolated by the usual methods did not take up the stain until it had been treated by sodium or potassium hydrate. Under these conditions it formed a jelly which took up the stain immediately. The latter reaction may therefore indicate the presence of pectic acid or pectates instead of pectin.

Work done by Harlow (12) on the reactions of stem tissues to a large number of staining reagents shows that great care is necessary in the chemical interpretation of staining reactions. He found " that in no instance was the action of any stain specific for certain layers of the cell wall, but that in all cases the middle lamella stained deepest while the remaining wall layers displayed a somewhat fainter colouration. There is, of course, no doubt that pectic substances are present in the cell-walls of apples, but we have very little experimental evidence indicating in what form and to what extent it does occur in the wall.

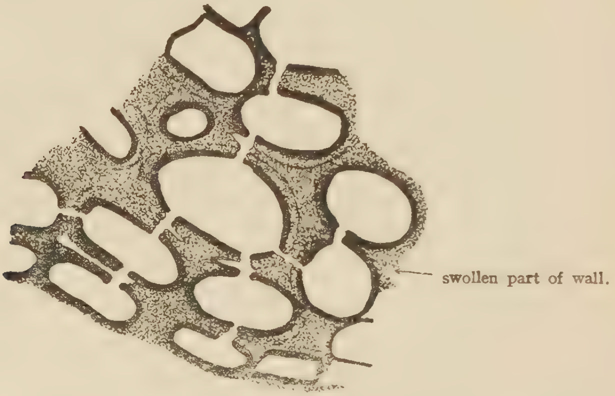

Fig. 10.
Cherry Pearmain, sub-epidermal tissue after boiling in H_2O, showing pits in cell walls.

A direct (i.e., without any previous treatment of the section by other reagents) stain by Ruthenium Red was not obtained in the earliest stages of development and its first appearance was in the middle lamella of apples with an average diameter of 1.3 to 1.5 c.m. and later the whole wall gave a reaction. No indications of uneven staining were obtained in sections of fresh material with the exception of a deeper stain at the corners where the wall came in contact with the intercellular spaces. The concentration of the " pectic material " in this position might be caused by its drying round these air-spaces. The holding together of otherwise disintegrating cells at this point during maceration experiments also pointed to this conclusion. Heavy staining reactions were obtained in the thick walled cells of the sub-epidermis and very distinct pits were noticed in these walls (Text Fig. 10). These could be made even more prominent by boiling the tissue or by treatment of the sections with sodium or potassium hydrate. The same pits were noted in the walls of the cells forming the cortex, but they were not nearly so obvious as those of the sub-epidermis owing to the thinness of the walls.

Occasional examples of "pectic" structures similar to those illustrated in Carré and Horne's paper were seen in apples gathered before the normal time, but as a general rule no sign of them could be seen until after the apples had gone into store. When seen in surface view, these took the form of circles of "pectic" material and when seen in a section of a cross wall they appeared as crescents or bands according to the way in which the section had happened to cut across the cell.

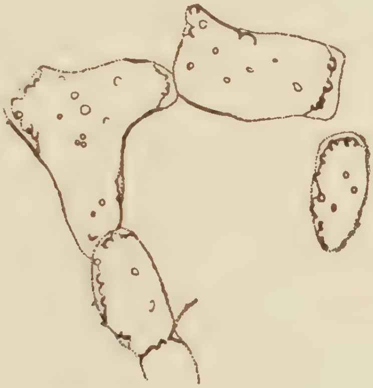

FIG. 11.

"Silver Cup" showing "pectin" deposits (represented by continuous line).

The examination of a large number of sections of several varieties led to the conclusion that the discs, crescents and bands of Carré and Horne were accumulations of "pectic" material round pits in the wall looked at from different points of view. Discs are described by Carré and Horne as follows: "Discs situated in the wall of contact of a particular cell stand opposite those present in the neighbouring wall of contact of the cell to which it is attached." Such an arrangement would be very unlikely unless the "pectic" substances were deposited in relation to definite wall structures in the nature of pits. The crescents and bands therefore would be merely sectional views of discs. The time of their appearance was found to be very variable and they gave no indications that their appearance was the beginning of the general break up of the pectic material of the cell-wall.

Experiments with macerating reagents showed that apple tissue was very resistant in its young stages. Alcoholic and aqueous potash, alcoholic and aqueous hydrochloric acid and ammonium oxalate produced no effect, a good middle lamella stain with Ruthenium Red being obtained after the sections had been acted upon for two days. Treatment with boiling alcoholic potash 30 per cent. usually brought about disintegration after it had been acting for some time and also 20 per cent. hydrochloric acid. When the apples were of a considerable size with a diameter up to 3.4 c.m. in the larger varieties, boiling water for one-and-a-half hours would bring about maceration in varieties with a high acid content such as Lane's Prince Albert, but not in a variety such as Sweet Alford in which little acid was present. This fact was noted by Barker (2) during the war when testing the culinary properties of cider apples. In Sweet Alford the cells were held together at the corners which stained with Ruthenium Red.

Series were set up in the later stages in which the various reagents were allowed to react for any length of time up to about three weeks. The most effective macerating agent in these experiments was 30 per cent. aqueous potassium hydrate. Separation of the cells began after seven days in the reagent and sections were very fragile and almost impossible to handle after twelve days. The middle lamella swelled and then dissolved away.

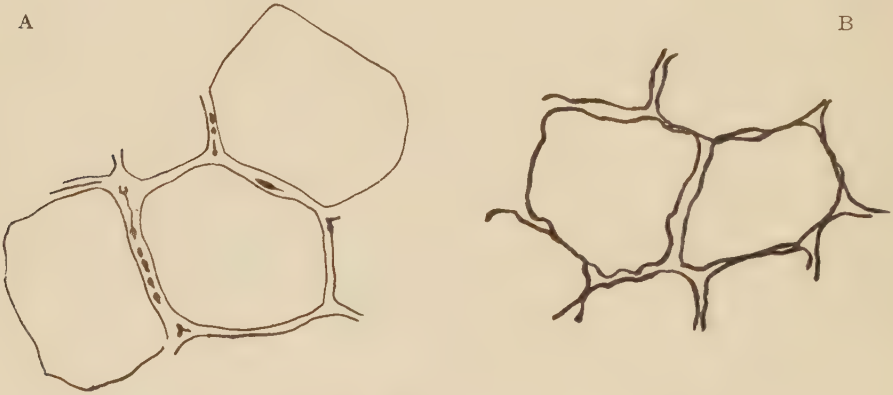

FIG. 12.
Effect of KoH on sections of Lane's Prince Albert.
A. 4 days in 3% KoH.
B. 17 days in 3% KoH.

The cell walls also swelled slightly but the "pectic" matter seemed to be removed more slowly from the wall as the compound formed was very gelatinous. This substance often kept whole sections together and the cells did not come apart until the coverslip was pressed slightly. In the later stages (from August onwards) maceration could be brought about by the use of hydrochloric acid followed by aqueous potassium hydrate, which suggested that the middle lamella at this stage was mainly an insoluble salt, possibly calcium pectate. Maceration by means of oxalic acid or ammonium oxalate on sections of Lane's Prince Albert, Medaille d'Or and Sweet Alford was unsuccessful. The latter was used successfully by Carré and Horne in the case of Bramley's Seedling. Ammonium oxalate for six days followed by 3 per cent. potassium hydrate for one day was effective on sections of Lane's Prince Albert after the sections had been previously boiled, but not in the other two varieties.

The results of these maceration experiments suggest that there may be some definite differences in the middle lamella of highly acid varieties of apples and that of apples with a low acid content. The presence of calcium pectate as a middle lamella constituent is still uncertain, but it may be present in the sweeter varieties.

SUMMARY.

1. An account is given of the developmental stages in the formation of the mature apple.

2. The structural peculiarities found in the epidermal layers of a range of varieties is given together with an account of the variations found in cork formation.

3. An alternative interpretation is suggested as to the meaning of the discs, crescents and bands of Carré and Horne.

In conclusion the writer would like to record her indebtedness to Professor J. H. Priestley and to Professor B. T. P. Barker for their helpful advice and especially to the latter for all the facilities provided for the work.

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THE RASPBERRY AND LOGANBERRY BEETLE AND ITS CONTROL: SOME EXPERIMENTS WITH A PYRETHRUM EMULSION SPRAY.

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Long Ashton Research Station.

The Beetle and its Ravages.

Byturus tomentosus, generally known as the Logan or Raspberry Beetle, is the most serious pest with which British growers of those two fruits have to contend. Indeed the infestations may become so severe as to ruin the bulk of the crops and render the fruit quite unfit for canning or bottling. Blackberries also suffer heavily, and there is little doubt that it was from wild plants of this berry that the infestation of cultivated Rubi arose in the first instance and is still being constantly renewed.

To the general accounts of the life history, etc., given by Theobald (1), Warburton (2) and others it does not seem needful to add, except to stress the following points. The adult beetles are on the wing in numbers for a considerable period prior to the opening of the flowers of Logan and Raspberry and during that time frequent other flowers, notably those of apple and pear. At Long Ashton specimens have been taken from plants as diverse as the Currant and Lilac.

Furthermore to quote Lees (3) (who also noted that the beetle could be found in apple flowers): " They feed on the tissue of the base of the flower, the nectaries being probably especially attractive. As they feed they destroy the base of the stamens but otherwise do not do much direct damage."

Warburton (2) states that " They pierce buds and prevent many of them from developing at all. Later they attack open blooms and feed upon stamens and petals. Much harm is done in these early stages . . ." After a detailed examination of some 18,000 fruits I am inclined to the view that the injury caused by the adult beetles at this stage is often by no means negligible. Apart from considerable scars left on the disc and base of the receptacle (the type of injuries mentioned by Lees) the basal and periphral drupes of such flowers frequently remain shrivelled and green, causing the fruits to be imperfect and to some extent malformed. These shrivelled " seeds " generally showed a puncture or scar. This type of injury may appear in cases where there is no larval damage to the receptacle, etc., and, in my experience, is certainly more abundant and serious in those plantations infested with beetles, and it seems highly probable that such injuries may be caused by the feeding habits of the adult beetles.

RÉSUMÉ OF PREVIOUS INVESTIGATIONS ON CONTROL.

In the absence of any corresponding review elsewhere, a short résumé of the progress of control measures in this country is perhaps called for here before proceeding to the account of the present investigations.

Theobald (1) advises pruning and burning of canes from infested plantations and the removal of brambles from the vicinity ; the hoeing, liming, etc., of the ground after attack ; jarring over tarred sacks, etc., and (from experiments in 1903 and 1908) the use of Arsenate of Lead as a spray.

In 1917 Lees (3) tested a combined nicotine-paraffin emulsion soft soap spray " which had already given good results against the beetle on a small scale." An infestation of 100 per cent. was reduced to one of 33 per cent., by three double sprayings in three weeks. It was found necessary to spray with paraffin emulsion ahead of the combined spray, in order to dislodge the beetles and secure a good kill.

In 1919 Lees (4) states of the above " The method though successful was rather expensive, and cannot therefore be considered as thoroughly satisfactory." Having noted that logans growing in soil well cultivated during the summer suffered less than others, Lees carried out a field trial designed to test out this method of control. Figures are given in the paper just mentioned and the results are summarised as follows. " There was a marked increase of infestation where no cultivation was done, but the difference between any of the treated rows was not sufficient to draw any definite conclusion."

Lees and Peren published in 1920 (5) the results of further trials, adding soap to a lead arsenate spray. No scorching occurred and the total percentage of infestation was reduced from 24 to 15 ; only two sprayings were made.

Again in 1921 the same workers (6) report on the results of three sprayings with Arsenate of Lead, the formula used being arsenate of lead 4 lbs., water 100 gallons. The applications were made when approximately " one-third of the bloom was out, the second when two-thirds were out, and the third when the bushes were in full bloom." The sprayed berries in this trial averaged 4.9 per cent. infested and the unsprayed 19.8 per cent.

In 1922, further and similar trials at Long Ashton were carried out (7), (8), and the results of three consecutive years' spraying are given in the articles cited, showing a consistent reduction of infestation on both the sprayed and control plots.

	Sprayed. per cent.	*Unsprayed* per cent.
1920	15	24
1921	4.9	19.8
1922	2.6	9.1

In 1925, the Ministry of Agriculture and Fisheries (9) referring to this pest state " Unfortunately no satisfactory means of dealing with the pest has yet been discovered. . . Under experimental conditions, spraying the open bloom with lead arsenate has given promising results, but is open to objection, firstly on account of the danger of poisoning bees, and secondly because the length of the flowering period would render several sprayings necessary."

In spite of these objections it would appear from the literature quoted that Messrs. Lees and Peren's method did effect a commercial control, and that any spray method would have to encounter the same difficulty, namely the prolonged flowering period of both raspberry and loganberry. A more real danger would seem to be in the persistent use of sprays containing arsenic. Be that as it may, the method does not seem to have come into very general use, since persistent complaints continued to be received from growers as to continued heavy infestations and losses.

EXPERIMENTS WITH PYRETHRUM SPRAYS.

One of the problems under consideration when the writer took up duties at Long Ashton in October, 1927, was the discovery, if possible, of some effective spray or dust which would not possess the poisonous properties of lead arsenate. The following pages detail the progress made so far in this enquiry in respect of the use of pyrethrum as the toxic agent.

Tutin (10) states " The insecticidal properties of the flowers of certain species of *Pyrethrum* have long been known, but as yet no satisfactory preparation of the active principles of these flowers adapted for employment in the field as a spray appears to have been devised " and refers to two recent sources of information (11) (12).

Tutin shows that the active principles present in Pyrethrum flowers (*P. cinerariæfolium*) may be readily extracted by means of light petroleum, and that the extracted active principles, when dissolved in a fatty oil (such as Rape oil) may be emulsified. An emulsion prepared in this manner, representing a concentration of 1 per cent. of the original flowers, when used as a spray, was rapidly fatal to a number of insect species, but caused no damage to vegetation.

Several references have recently been made in various journals and reports regarding progress made on the growth of *P. cinerariæfolium* in Britain, whilst articles by Austin and Theobald 1928 (13) and Austin 1929 (14) refer to experiments on various insects carried out at Wye, using aqueous and alcoholic extracts respectively. No mention is made in these, however, of *Byturus tomentosus* as an object of test.

In Tutin's paper (10) details are given as to the effects of his pyrethrum spray on a number of insects, under laboratory conditions and including the Logan Beetle. He also refers to some small scale field trials conducted by myself. Details of these not having been published previously, they will be given here before the more extensive trials of 1929 are described.

FIELD TRIALS IN 1928.*

It was not anticipated at the outset that any field trials could be made during the summer of 1928. Since, however, the laboratory trials were so promising and were so expeditiously carried through, it was decided to attempt something that year, however small, since any experience of field conditions would be of great value for more extensive work in 1929. The limited amount of the spray material available only allowed of one spray application being made; this was applied to heavily infested loganberry plants situated (*a*) in gardens in the village of Long Ashton and also (*b*) on a commercial plantation in Herefordshire.

In the case of (*a*) Logans were sprayed on June 6th by means of a hand machine, approximately one-third of the flowers being set, one-third being open, and one-third still in bud. An equal length of canes was reserved as a control. Six pickings were made from both plots between June 26th and July 27th, the entire crop from both sprayed and control canes being dealt with—totalling 24 yards run of canes. In all 677 fruits were picked and the effect of the spray was clearly seen. On July 7th the infestation on the sprayed plot was 53 per cent. and on the control 56 per cent. On the 10th the sprayed plot gave 39.37 per cent. and on the control 79.16 per cent. On the 13th the figures were 68 per cent. and 87.57 per cent. respectively.

In (*b*) an area of one-seventeenth acre was sprayed by means of a knapsack, the flowering condition being similar to that of (*a*). The weather was dull and few adult beetles were on the flowers only 27 being found on 500 flowers.†

A picking was made on July 20th when (as nearly as could be judged) the fruits from the sprayed blooms were ready. 1,200 fruits were examined—600 from sprayed and 600 from control canes.

The controls showed an infestation of 40.87 per cent. and the sprayed 30 per cent. The owners kindly carried out further counts involving some thousands of fruits, but no reduction was shown by these.

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* In the case of these trials, as also of those conducted in 1929, the spray mixture used was prepared as described by Tutin (*loc. cit.*) under the heading of "Use of the Pyrethrum Spray in the Field." For example, the crude pyrethrins extracted from 100 lbs. of the flowers were dissolved in 15 gallons of Rape oil and 5 gallons of Agral W.B. added. When required for use, 2 gallons of this mixture were added to 98 gallons of water, 2 pints of 40% aqueous caustic soda then added, and the mixture stirred. Cotton seed oil may be used in place of the Rape oil. It is not desirable to mix the oil solution of the crude pyrethrins with the Agral W.B. earlier than is convenient, since the mixture containing the Agral suffers slow loss of insecticidal power on keeping. The emulsification by means of alkali should never be effected until immediately before use.

The spray mixture prepared in this manner causes no injury to even the most delicate vegetation.

† During the afternoon the sun shone, and in another field 37 beetles were obtained from 100 flowers.

It may be mentioned here that a row of Raspberries was sprayed at Long Ashton on May 18th just as the first flowers opened in order to test any deterrent effect the spray might have. Subsequent counts showed no significant difference between the sprayed and control plots. The average infestation here proved to be only 9.5 per cent. (between June 26th and July 13th on 1,594 fruits examined). This brings out an interesting point. It has been stated that where Logans and Raspberries are grown in close proximity, the beetles show a decided preference for Logan flowers for purposes of oviposition. This is borne out by the above figures since the Raspberries mentioned were situated some 30 yards from the Logans used for experiment (*a*) where the average infestation (July 6th to 13th) was 74.24 per cent. The highest infestation recorded on the Raspberries was 33 per cent. on July 13th.

In another garden in Long Ashton a short row of Logans showed an infestation of 68.3 per cent. on July 13th, whereas a row of Raspberries only separated by a narrow path gave an infestation of 24.5 per cent.

Mr. F. Tutin informs me that he has noted a corresponding preference for Phenomenal Berry when these are grown in proximity to Logans. It would seem that these facts might be turned to practical account, by the use of these preferred plants, either inter-planted as " traps " or around the margin of new plantations. The latter alternative is suggested since experienced growers state that the infestation of these proceeds progressively inwards from the margins and hedges. Such " traps " could be sprayed, or all fruits picked and destroyed. An experiment along these lines certainly seems indicated.

Lees and Peren (4) state for their 1920 field trials that " It is clear . . . that in the unsprayed portions there is a well marked increase in the number of infected berries as the season advances. This is due to unknown causes, but may be attributed to the increasing number of beetles that come out of winter quarters as the season progresses."

Whether or not that explanation is correct, it will be seen from figures given for the 1928 field trials, and those that follow (for 1929) that this progressively increasing infestation is a notable fact, and can be seen in both control and sprayed plots.

FIELD TRIALS IN 1929.

These were twofold (A) on Logans, in gardens at Long Ashton and (B) on Raspberries near Evesham. The former fruit was intended as the main trial, but owing to very serious frost injury to the plantations originally selected, these had to be abandoned, and the major trial was carried out on a commercial plantation of Raspberries.

Loganberries.

Heavily infested plots were selected and sprayed with an efficient bucket pump on June 1st, 7th and 21st, part of each plot being left unsprayed as a control. Rain and high wind caused delay in applying the third spraying. Six pickings were made, and the results are set out in Table A.

Raspberries.

A heavily infested plantation near Evesham was used for this trial, the variety being Lloyd George. Three-fifths of an acre was sprayed on June 5th, 19th and 25th, when approximately one-third, two-thirds and all the flowers were fully open. The second application was about five days later than intended owing to high winds. The owner considered that the first and last sprayings could be regarded as " best dates." 175 gallons of wash were used on June 5th, being at the rate of about 300 gallons per acre. The spray was applied by means of automatic knapsacks by two men per row.

When the first spraying commenced, 100 typical flowers were examined and yielded 65 beetles. After the sprayers had passed, another 100 flowers gave 12 beetles; these were kept for 24 hours, when 8 were dead, the other 4 recovering.

On July 10th, just as the grower commenced his first picking, random samples of 200 fruits were taken from both sprayed and control plots and examined at once. These yielded as follows :—

	Clean.	*Infested.*	*Infestation.* per cent.
Sprayed	173	27	13.5
Control	70	130	65.0

Thus showing a reduction of infestation of 51.5 per cent.

Five successive commercial pickings from the plot were made in due course by the grower, and a day prior to each, 1,000 fruits were picked from the sprayed and control plots respectively (10,000 in all) and placed in a 2 per cent. formalin solution in screw top jars and the whole finally brought to Long Ashton, where they were subsequently examined, one by one, in the laboratory.

The actual picking was done by the same person throughout, after preliminary instruction. This picker took a random sample of 200 from each row per pick (100 from each side of each row) and placed these in a separate labelled and numbered jar, so that each row could be compared separately throughout.

The fruits were picked on the stalk, and were pulled apart at counting, when a considerable proportion (especially from the first and second pickings), were examined under a low power Zeiss binocular microscope. During this process a total of 173 were rejected either through prior disease or injury other than that caused by *Byturus*, which rendered them unsuitable for critical work. The details of these counts are set out in Table B.

The author is indebted to the grower for the following figures relating to crop weights and picking dates in the 1929 field trials on raspberries. The proportionate crop weights for the five commercial pickings were 65, 65, 104, 61 and 38 respectively out of a total of 333.

Reference to Table B. will show that the average percentage infestation of the control plot was 56.69, whilst that of the sprayed plot was 18.17, the difference indicating an average reduction of infestation of 38.52 per cent. The total crop weight being represented by the figure 333, it is evident that for the first three pickings, representing 70 per cent. of the total crop, the reduction of infestation was 46.13 per cent., whilst for the last two pickings, representing 30 per cent. only of the crop, the reduction was but 27.09 per cent., a matter of considerable economic significance. This is a point which will call for more detailed consideration as this work becomes further advanced.

Blackberries.

Several large bushes of a special garden variety were sprayed twice—June 28th and July 10th—in a private garden at Long Ashton, by the owner. Unfortunately no controls were left, and since comparison was therefore impossible, no counts were made. The owner estimates the subsequent infestation at 20 per cent. out of a very heavy crop and states that in previous years the majority of fruits were ruined by the larvæ of *B. tomentosus.*

ACKNOWLEDGMENTS.

Thanks are due to the British Dyestuffs Corporation Ltd., who very kindly supplied the pyrethrum flowers and other materials necessary, and also extracted the crude active principle, thus providing the requisite materials for the 1929 trials.

Acknowledgment must also be made to Mr. G. Marshall, Breinton, Hereford and also Prof. B. T. P. Barker and Mr. G. T. Spinks for facilities in carrying out the Loganberry trials, whilst Mr. A. H. Hiller of Dunnington Heath, near Evesham, spared no trouble to make the Raspberry trial of 1929 a success. The writer also wishes to thank Mr. J. C. F. Fryer and Mr. F. Tutin for very helpful suggestions, assistance and encouragement throughout the work.

SUMMARY.

1. An account is given of field experiments in 1928 and 1929 with a Pyrethrum emulsion for the control of *Byturus tomentosus*, the Logan and Raspberry Beetle.

2. The promising results obtained in 1928 were confirmed in 1929, a reduction in infestation as high as 49.86 per cent. in the case of the raspberry, and of 55.26 per cent. in the case of the loganberry being obtained. These results, which can be considered as a "commercial control," suggest that Pyrethrum sprays of this type are worth an extended commercial trial.

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TABLE A.

Date of Picking.	Control.				Sprayed.		
	Free.	Infested.	% Infestation.	Remarks.*	Free.	Infested.	% Infestation.
	Garden A.						
11/7/29	9	91	76.21	All counted.	16	—	—
17/7/29	51	249	80.30	All counted.	200	52	20.63
22/7/29	28	172	86.00	Random sample.	214	86	28.66
25/7/29	35	165	82.50	Random sample.	215	85	28.33
29/7/29	47	153	76.50	Random sample.	233	57	22.33
1/8/29	11	89	89.00	All counted.	163	87	34.80
	Garden B.						
11/7/29	55	178	76.39	All counted.	163	31	15.97
17/7/29	150	350	70.00	Random sample.	451	49	9.80
22/7/29	182	318	63.66	Random sample.	418	82	16.40
25/7/29	169	331	66.20	Random sample.	418	82	16.40
29/7/29	169	331	66.20	Random sample.	409	91	18.20
1/8/29	87	163	65.20	All counted.	379	121	24.20
			Dates of spraying—June 1st, 7th and 21st, 1929. (Third application delayed by rain.)				
				Summary.			
Totals.	*Garden A.* 181	919	81.75	Average of Infestation.	1,041	377	22.45
	Garden B. 1,671	812	67.94	,, ,,	2,238	456	16.82
Gardens A & B.	1,852	1,731	74.84	,, ,,	3,279	833	19.63

* These remarks also apply to the " sprayed " columns.

TABLE B.

Dunnington Heath Trials, 1929. *Raspberry Fruit Counts.*

	Control Plot.		*Sprayed Plot.*	
	Fruits.		Fruits.	
Row.	Free.	Infested.	Free.	Infested.
	Date of Picking—10/7/29.			
1	85	113	162	22
2	91	108	177	18
3	116	81	191	11
4	117	81	184	9
5	117	83	183	7
Totals	526	466	897	67
	% Infested Fruits 46.97.		% Infested fruits 6.95.	
	Date of Picking—15/7/29.			
1	92	107	174	29
2	74	114	180	16
3	77	119	176	21
4	73	125	179	18
5	68	129	169	23
Totals	384	594	878	107
	% Infested Fruits 60.73.		% Infested Fruits 10.87.	
	Date of Picking—18/7/29.			
1	74	127	162	36
2	57	140	164	36
3	56	145	169	27
4	66	128	160	37
5	81	120	160	40
Totals	334	660	815	176
	% Infested Fruits 66.39.		% Infested Fruits 17.86.	
	Date of Picking—22/7/29.			
1	89	112	158	42
2	71	126	151	45
3	101	95	154	43
4	97	103	157	35
5	105	93	154	34
Totals	463	529	774	199
	% Infested Fruits 53.33.		% Infested Fruits 20.46.	
	Date of Picking—24/7/29.			
1	83	107	144	42
2	93	102	110	45
3	78	117	148	43
4	80	128	123	35
5	100	99	109	34
Totals	434	553	634	199
	% Infested Fruits 56.03.		% Infested Fruits 34.71.	

Dates of Spraying—June 5th, 19th and 25th, 1929. (Second application delayed by rain.)

Total Fruits Examined—(a) Sprayed	4,884
(b) Controls	4,943
Total	9,827
Average Infestation of Controls	56.69
Average Infestation of Sprayed	18.17
	38.52

PROGRESS OF INFESTATION.

% of Infested Berries.

	Control Plot.	*Sprayed.*	*Difference.*	*Average.*
1st Picking	46.97	6.95	40.02	46.13
2nd ,,	60.73	10.87	49.86	
3rd ,,	66.39	17.86	48.53	
4th ,,	53.33	20.46	32.87	27.09
5th ,,	56.03	34.71	21.32	

(*Received* 14/2/30.)

THE CONTROL OF THE FRUIT TREE RED SPIDER

(*Oligonychus ulmi* C. L. KOCH)

OF PLUM DURING THE GROWING SEASON.

By A. M. MASSEE.

Research Station, East Malling.

Introduction.

An experiment was elaborated during the Spring of 1929, in collaboration with Mr. R. V. Harris, of the Mycological section of this Station, with a view to testing lime-sulphur and other fungicidal and acaricidal preparations, for the dual purpose of controlling at a single application the Bacterial Canker of plum and the Fruit Tree Red Spider.

After the various sprays had been applied to the trees, it was found that the leaf spot stage of the Bacterial Canker, which in former years had been prevalent on these particular plum trees, did not develop on sprayed or control trees to any marked extent during the growing season of 1929. Thus the experiment had to be abandoned so far as the Mycological aspect was concerned. Fortunately, the Fruit Tree Red Spider proved to be present in large numbers on most of the trees, and it was decided to continue the observations from an entomological standpoint.

The Fruit Tree Red Spider is one of the most troublesome pests which occurs on plums at the present time.

The recent increase of this mite on plum is due, in all probability, to the annual application of tar-distillate which is of necessity applied to plums during the dormant season. It has been established that this winter wash is not toxic to the eggs of this mite,* and also that a number of predaceous insects which partially feed upon the mite are destroyed as a direct result of winter washing with a tar-distillate.

However, it has been proved beyond doubt that many of the more serious insect pests of plum, e.g., the Leaf Curling Plum Aphis and the Winter Moth, are controlled efficiently by means of these tar-distillate sprays. Lees and Briton-Jones† also point out that the Brown Rot disease of plum is completely controlled by these sprays, and for these reasons alone the spraying of plums must be continued where these pests and diseases abound.

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* Tar-Distillate Washes and Red Spider. A. M. Massee and W. Steer. *Jour. Min. Agric.*, 1929. 36. 253-257.

† Plum Aphis and Brown Rot. Lees and Briton-Jones. *Jour. Pomology*, 1925 IV. 196-199.

The Fruit Tree Red Spider of plum is the same species of mite as that commonly found on a apple. Now, it has been shown elsewhere* that when this mite occurs on apple it may be controlled to a large degree by spraying the trees in the Spring, when the blossoms reach the " pink bud " stage. A lime-sulphur spray applied at the rate of one gallon of lime-sulphur to thirty gallons of water is recommended for this purpose. Unfortunately this strong pre-blossom lime-sulphur spray cannot be used against the same mite on plum trees. The reason is obvious, because very little good would be accomplished by applying the spray earlier in the season than the " pink-bud " stage of the apple, since the spray is intended to kill the mites by contact (it is known that lime-sulphur does not effect the eggs) as soon as they emerge from their winter eggs, and the hatching period of a majority of the mites is just before the flowering of the apple, and at this season many of the commercial varieties of plums are in full flower.

For this reason it was decided to carry out an experiment to determine whether lime-sulphur and other preparations could be used safely on plums, (without causing spray injury) after the blossom period.

MATERIAL AVAILABLE.

Nine rows, each consisting of twenty-nine trees of nine years' old Victoria plum trees growing at the Research Station on known root stocks, were available for this investigation.

The Victoria plum trees proved ideal for the purpose because the winter eggs of the Fruit Tree Red Spider were very plentiful, and were pretty evenly distributed on a majority of the trees.

The whole plot had been sprayed with a tar-distillate wash (10 per cent.) in January, 1929.

HATCHING OF THE MITES.

The trees were examined periodically during April and May and a record of the hatchings of the mites was obtained. For some unaccountable reason hatching was delayed considerably, compared with the hatching records of previous years, and very few active mites were noticed before the first week of May. During the first and second weeks of May the mites hatched out with great rapidity, and by May 17th a majority of the winter eggs had hatched.

By this time most of the immature mites were already feeding on the leaflets, while others were to be seen running up and down the shoots as though in search of food.

The plum trees came into bloom during the last week of April and all the petals had fallen by the 8th of May.

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* The Fruit Tree Red Spider. A. M. Massee. East Malling Res. Sta. Ann. Rep. for 1928 (April, 1929). I. General, 116-122.

SPRAYS USED.

As already mentioned this investigation was intended to be a joint piece of work by the Mycological and Entomological Sections. Therefore, all the sprays selected for this test were known to contain fungicidal and acaricidal properties.

In addition, since it could not be stated with certainty when the leaf spot stage of the bacterial canker would develop on the foliage, it was planned to spray certain rows of trees two or three times, at intervals of about two weeks between each spraying. Again, it was not known how the bacterial canker spread from one tree to another, or even from branch to branch, but since there was a possibility of the disease being carried by insects, e.g., the Brown and Green Leaf Eating Weevils, it was decided to add arsenate of lead paste to one of the sprays, in the hope of destroying such insects and thus preventing the spread of the disease.

The treatment of each row of trees can be ascertained by reference to the following key :

Row.	Treatment.	No. of Applications.
A.	Untreated " Controls " (alternate trees)	—
A.	Lime-sulphur 1 : 99+ .1% Gelatine	1
B.	,, ,, ,, ,, ...	2
C.	,, ,, ,, ,, ...	2
D.	Lime-sulphur 1 : 99+ .1% Gelatine+4 lbs. arsenate of lead paste ..	2
E.	Lime-sulphur 1 : 99+ .1% Gelatine	2
F.	White oil emulsion 1 : 99	1
G.	Bordeaux 8 : 12 : 100+ .1% Gelatine+1% white oil emulsion* ..	3
G.	Untreated " controls " (alternate trees)	—
H.	Bordeaux 8 : 12 : 100+ .1% Gelatine+1% white oil emulsion ..	3
H.	Untreated " Controls " (alternate trees)	—

* White oil emulsion used in first application only.

All the sprays were applied by means of a power sprayer ; a pressure of 150 lbs. per square inch being used in each case. A fine nozzle and a number 1 disc was used for the first application and a number 0 for the second and third applications. The untreated " controls " were protected against any of the spray drifting by means of large sacking screens, which proved very efficient for the purpose.

The weather conditions at the times of spraying were good, but the wind was a little troublesome at times while the first application was being made. The second application was carried out during warm, sunny weather, and the sprays dried very readily on the foliage and branches. A westerly breeze and light clouds prevailed during the period of the third application. The weather was sunny and warm.

The first sprays were applied on May 22nd about fourteen days after the fall of the plum blossom ; the second application was made on June 6th, or about fourteen days later ; and the third on June 22nd.

OBSERVATIONS UPON THE MITE IN THE FIELD.

In order to determine whether the mites had been killed by the sprays a record of the number present on some of the leaves of sprayed and unsprayed trees had to be obtained in the field.

For this purpose twelve leaves were selected from each tree, and the number of living mites upon them were recorded. These leaves were picked from approximately the same position from each tree, and from branches about the same height from ground level.

After a little practice this operation could be conducted in the field without difficulty. A hand lens usually proved suitable for determining whether the mites were dead or alive, but a binocular microscope was always at hand in order that doubtful specimens could be examined more carefully. The first counts were obtained from May 27th-30th inclusive, and the second counts on June 3rd, 4th and 5th.

The following tables show the number of mites recorded on the leaves examined in each treatment and the controls.

TABLE I.

Showing number of mites present on leaves of unsprayed trees. Twelve leaves examined on each tree at each count.

Tree No.	Treatment.	No. of Mites on leaves.	
		1st count.	2nd count.
2	Unsprayed " control " trees.	41	32
4		119	220
6		43	132
8		117	145
10		114	67
12		8	135
14		0	3
17		154	167
19		76	114
21		208	174
23		103	114
25		44	78
27		96	85
29		0	13

TABLE II.

Showing number of mites present on leaves of sprayed trees. Twelve leaves examined on each tree at each count.

Tree No.	Treatment.	No. of Mites on leaves.	
		1st count.	2nd count.
1	Lime-sulphur 1 : 99+ .1% Gelatine.	1	1
3	,,	2	0
5	,,	14	4
7	,,	24	3
9	,,	4	3
11	,,	41	4
15	,,	12	3
18	,,	49	3
22	,,	37	4
24	,,	5	2
28	,,	5	5

TABLE III.

Showing number of mites present on the leaves of sprayed and unsprayed trees. Twelve leaves examined on each tree at each count.

No. of Trees.	Treatment.	No. of Mites on leaves.		Mean per tree.	
		1st count.	2nd count.	1st count.	2nd count.
26	Lime-sulphur 1 : 99+ .1% Gelatine+4 lbs. lead paste	77	45	3	2
26	White oil Emulsion 1 : 99	403	622	15.5	24
8	Bordeaux 8 : 12 : 100+ .1% Gelatine+1% white oil emulsion.	486	419	61	52
18	Untreated "controls."	1,319	1,016	73	56

Table I. shows the number of mites recorded on the leaves of the control trees. The trees were growing in the same row as those sprayed with lime-sulphur and the distribution of the mites was approximately the same on both sets of trees previous to the application of the sprays. It will be seen that very few mites were recorded on trees 14 and 29. These were the exceptions and for for some unknown reason they remained comparatively free from attack throughout the season, and could be readily picked out from the rest of the unsprayed trees until leaf fall. The mite population of Tree 12 was also interesting. At the first count only eight mites were recorded, while 135 were noted during the second examination. At the beginning of the season the mites were not evenly distributed on this tree, but by the end of the summer the whole tree was badly infected. The remainder of the control trees were heavily infected throughout the summer as indicated by the figures in columns three and four.

The number of mites recorded on the leaves which received the lime-sulphur spray (1 : 99) are shown in columns three and four of Table II. It will be seen that very few living mites were found on the foliage, and they were only observed by very careful observation. Trees 11, 18 and 22 were more heavily infected at the time of the first examination. Later on, however, very few living mites were noted on the leaves of these trees.

The figures show very clearly that the lime-sulphur spray considerably reduced the number of mites per tree. This point was confirmed—only much more strikingly—by comparing the sprayed and unsprayed trees in the field. In every case the untreated trees (with the exception of trees 14 and 29) could be picked out, first, by the unhealthy appearance of the leaves and second by the large number of mites upon them. On the other hand it was difficult to detect the mites on the sprayed trees.

The same story might be told of all the trees which received the lime-sulphur spray. For example, the trees which were sprayed with lime-sulphur plus arsenate of lead paste were almost free from mites as a result of the one spraying. The figures are presented in Table III., 312 leaves from 20 trees were examined and only 77 mites were found on them. A similar number of leaves were examined one week later and this time only 45 living mites were observed.

The trees which received the White Oil emulsion (1 per cent.) and those sprayed with Bordeaux Mixture plus White Oil Emulsion did not present the same healthy appearance as those sprayed with lime-sulphur, and in fact nearly as many mites were recorded from some of these trees, as upon the unsprayed trees. Full details are given in Table III.

On June 17th, eleven days after date of the second application of sprays, a third survey of the trees was undertaken in the field. On this occasion it was found that only a very small number of mature mites were present on the leaves of the sprayed and unsprayed trees. A majority of the mites had deposited their summer eggs on the leaves, and had died as soon as the oviposition period had been completed.

Thus, for this third inventory the number of summer eggs deposited upon the leaves had to be recorded. Twelve leaves were picked from each of the sprayed and unsprayed trees, and in order to get an exact record of the number of eggs per leaf, the examination was undertaken in the laboratory, by means of a binocular microscope. This work proved very tedious and occupied a good deal of time.

The leaves of the unsprayed trees and the lime-sulphur treatments were examined for the third time in this manner. It was considered unnecessary to examine leaves from the trees sprayed with the white oil emulsion and Bordeaux, since it was evident that these sprays did not control the mite to any marked degree.

Tables IV. and V. show the number of eggs recorded on the leaves of unsprayed trees and those sprayed with the lime-sulphur wash.

TABLE IV.

Showing number of Fruit Tree Spider eggs present on leaves from unsprayed "control" trees.

No. of Tree.	Treatment.	No. of Fruit Tree Red Spider Eggs Present.
2	Unsprayed.	271
4	,,	759
6	,,	287
8	,,	537
10	,,	250
12	,,	264
14	,,	2
17	,,	359
19	,,	570
21	,,	353
23	,,	306
25	,,	327
27	,,	218
29	,,	63

TABLE V.

Showing number of Fruit Tree Red Spider Eggs present on leaves of Trees sprayed with Lime-Sulphur Wash.

No. of Tree.	Treatment.	No. of Fruit Tree Red Spider Eggs Present.
1	A. Lime-sulphur.	28
3	,,	7
5	,,	25
7	,,	35
9	,,	0
11	,,	72
15	,,	83
18	,,	16
22	,,	12
24	,,	43
28	,,	23

It will be seen that 4,566 eggs were recorded from 168 leaves from the control trees, while only 344 eggs were found upon 132 leaves examined from the lime-sulphur row.

The figures speak for themselves and it is considered that the absence of eggs on the sprayed leaves is due to the fact that most of the mites were killed by the spray, before they deposited their summer eggs on the leaves.

It is of interest to note that the two control trees, 14 and 29 (Table IV.) were comparatively free from infection, and only two and 63 eggs were recorded upon them. It has been pointed out already that these trees were only slightly attacked throughout the Summer and this would account for the small number of eggs recorded upon them.

Of the sprayed trees numbers 11 and 15 were more severely attacked than the others, but even so these trees were comparatively free compared with the unsprayed trees.

Rows B., C., D. and E. which received two applications of lime-sulphur were also comparatively free from mite infestation and very few eggs could be found on the leaves.

The trees sprayed three times with Brodeaux Mixture and those sprayed once with the white oil emulsion were literally covered with mites in all stages, and their eggs, and by the middle of July the foliage was distinctly discoloured by their continuous feeding of the acari. In appearance these trees were similar in all respects to the unsprayed " control " trees.

The trees were examined from time to time during the summer, the final inspection being made in September prior to the leaf fall. All the trees sprayed with the lime-sulphur (1 : 99) could be distinguished from the other treatments and control trees at some distance from the plot. The foliage of these trees retained their natural colour until leaf fall, while the leaves of all the other trees turned brown in colour, and many of the latter were defoliated prematurely. By this time the mites were busily engaged in depositing their eggs on the spurs and other protected parts of the branches. While it is true that eggs could be found on all trees, including those sprayed with lime sulphur, a majority of the eggs were found on the unsprayed trees and those sprayed with Bordeaux or the white oil emulsion spray.

It seems reasonable to suggest that if the whole plot had been treated with the lime-sulphur wash, very few eggs would have been present on the trees in the autumn. In this experiment the unsprayed trees were scattered all over the plot, and there is little doubt that many mites migrated from the unsprayed to the sprayed trees.

Another observation seems to be of interest. It was noted that all the trees sprayed with the Bordeaux Mixture appeared to be more heavily infected with mites than the rest of the trees on the plot, including the controls.

This might be explained by the fact that many kinds of insects are driven away from the trees, as a result of the Bordeaux spraying, and since it is known that the mites are unharmed by this spray, they would naturally breed more rapidly when not checked by predaceous insects.

In addition it was noted that two species of Plum Leaf Hoppers were not nearly so common on the trees sprayed with the Bordeaux Mixture, and it appears that these insects were either driven away or killed by this spray. Parrott* also found that Bordeaux Mixture might be used with success for the control of the immature stages of Leaf Hoppers on apple trees.

In conclusion it should be stated that the success of the lime-sulphur, when used for the control of the Fruit Tree Red Spider, depends largely upon the date of the application of the spray. The spray should be applied when the majority of the winter eggs have hatched, and before the mites from these winter eggs have commenced to deposit their summer eggs on the leaves. Unfortunately, this period varies each season, but generally speaking there is sufficient time to get the spraying completed before the summer eggs are laid on the leaves. In practice the spraying should be carried out about two weeks after the blossom period, when the fruitlets are developing as illustrated by Fig. I.

SPRAY INJURY.

It was not understood with any degree of certainty at the time of spraying whether lime-sulphur and Bordeaux would cause spray injury to the foliage or affect the crop in any way, thus detailed notes on this important aspect had to be obtained. Eighty-three branches of treated and unsprayed trees were selected for this purpose, and the number of fruitlets on each were noted. In each case the branches were chosen from the south-west side of the trees, and each was approximately six feet from ground level.

The first count was recorded the day following the application of the first series of sprays, the second count was made one day after the second application of sprays, and the third count followed immediately after the date of the third spraying. Each shoot was labelled, and the number of fruits upon it were counted systematically.

Table VI. shows the number of fruits recorded on sprayed and untreated branches.

It will be seen that the greater number of fruits were recorded in the first and second counts as shown in columns three and four. This was to be expected because these counts were made prior to the stoning period of the plums. The figures in the fourth column represent the number of fruits which matured on the selected branches of sprayed and unsprayed trees. This count was made on June 21st, when all the small and shrivelled fruitlets had dropped off and when the stoning period had been completed some little while. It will be noted that the

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* Parrott, P. J. A Summary of Important Insects and Spray Developments. Proc. 72nd Ann. Meet. New York State Hortic. Soc. Rochester, N.Y., pp. 4-13, 1927.

TABLE VI.*

Showing number of Fruits Recorded on Selected Branches of Sprayed and Unsprayed Trees.

Treatments.	No. of Trees.	Average Number of Fruits per branch.			Percentage left on tree at Picking.	
		1st count.	2nd count.	3rd count.	Mean per tree.	Standard Error.
Lime-sulphur	20	69	57	4.9	6.0	1.1
Lime-sulphur + Arsenate of Lead Paste	10	55	50	2.2	4.2	0.9
White Oil Emulsion . .	10	81	73	4.5	5.3	1.0
Bordeaux Mixture + White Oil Emulsion	18	91	63	3.7	4.6	0.6
Control	25	62	47	2.8	4.3	0.8

number of fruits recorded in the final count was quite small, and as a matter of fact there happened to be a very poor crop on both sprayed and unsprayed trees. A comparison of the sprayed and unsprayed trees shows that the number of fruits in each case is about the same, and there is no significant difference in the percentage left on the trees anywhere. Therefore it can be assumed that the sprays did not cause fruit drop, and incidentally the fruits were not marked or russeted by any of the sprays.

Detailed observations in the field showed that none of the sprays caused any trace of injury to the foliage, and even the small partly opened leaves at the tips of the shoots were unharmed by the sprays. The trees were examined again after the second and third sprays had been applied, and no trace of injury could be found anywhere on the plot.

The writer is greatly indebted to Mr. M. Beshir for general assistance in this work, and to Mr. R. V. Harris for his help in planning the experiment and personally supervising the spraying.

SUMMARY.

It is pointed out that the Fruit Tree Red Spider, *Oligonychus ulmi* C. L. Koch) is a very serious pest of plum in this country, and that this mite occurs very commonly in orchards which have been sprayed during the dormant season with a tar-distillate winter wash.

It is further demonstrated that it is essential to continue using the tar-distillate washes in spite of the fact that the Fruit Tree Red Spider is not

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* The writer is very greatly indebted to Mr. T. N. Hoblyn for the arrangement of this table.

controlled by these sprays. Other important pests and diseases such as the Plum Aphides, the Winter Moth and Brown Rot are controlled as a result of tar-distillate spraying.

That the Fruit Tree Red Spider can be controlled by spraying the plum trees during the growing season, about two weeks after the blossoms have fallen, with a lime-sulphur spray.

That the spray should be applied at the rate of one part of lime-sulphur to 99 parts of water.

That the lime-sulphur spray does not reduce the crop, or cause any form of injury to the foliage or fruits.

That white oil emulsion (1 per cent.) and Bordeaux Mixture (8 : 12 : 100) are not toxic to the mites at the strengths used.

(*Received* 19/3/30.)

NINTH INTERNATIONAL HORTICULTURAL CONGRESS, LONDON, 1930.

The Ninth International Horticultural Congress will be held in London at the invitation of the Royal Horticultural Society and on its premises from August 7th to August 15th, 1930, immediately before the Fifth International Botanical Congress, which is being held in Cambridge from August 16th to August 23rd.

Besides the main subject for discussion at the Congress, namely "Propagation, Vegetative and Seminal," papers have been promised dealing with various aspects of fruit-growing at home and abroad. Many eminent horticulturists throughout the world have already signified their intention of being present, and have promised papers, while the Committees appointed at the Eighth International Horticultural Congress, 1927, in Vienna, will present their reports on Nomenclature, Awards, Colour, etc.

The Programme for the Congress, besides the lectures, will include excursions of horticultural as well as of general interest, and a special exhibition.

Papers, Communications to the Congress, and participation in the general discussion will be permissible in English, French and German.

CONFERENCE OF EMPIRE HORTICULTURISTS.

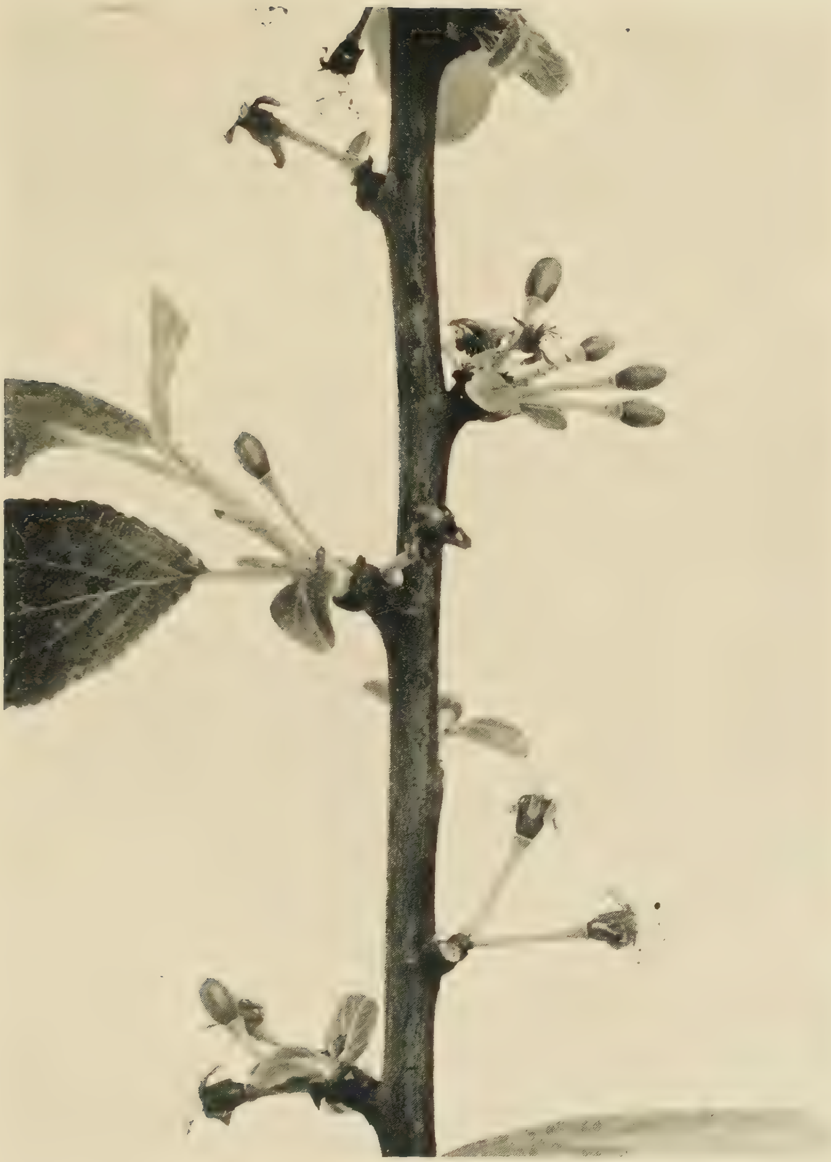
Advantage is being taken of the meeting in London next August of the Ninth International Horticultural Congress, and the consequent presence in this country of horticulturists from different parts of the Empire, to organize a Conference of British Empire Horticulturists for the days immediately preceding this Congress.

The Conference will be organized by the Imperial Bureau of Fruit Production, The Research Station, East Malling, Kent, and will take place on August 5th-7th.

It is hoped that the Conference will form the basis for valuable discussion and interchange of ideas between Horticulturists throughout the Empire. Papers will be given by leading horticultural experts from this country and from overseas, the following subjects receiving consideration :—

The work of the Imperial Bureau of Fruit Production ; Possible development of fruit growing in the Empire ; Methods of horticultural research, such as the lay-out of field experiments, the application of soil survey work and meteorological observations, and approach through the pure sciences. Progress in fruit storage methods will also be reviewed, and the sources and training of horticultural research workers discussed.

The Conference will be opened by Sir Robert Greig, M.C., LL.D., Chairman of the Executive Council of the Imperial Agricultural Bureaux, at 10 a.m. on Tuesday, August 5th. Further details may be obtained on application to the Imperial Bureau of Fruit Production, or to the headquarters of the Imperial Agricultural Bureaux, 2, Queen Anne's Gate Buildings, Westminster, S.W.1.



[Photo R. V. Harris.

PLATE I.

THE DEVELOPING FRUITLETS OF A VICTORIA PLUM TREE.

Showing the correct period to apply the post blossom lime-sulphur spray.

BOOK REVIEWS.

NORTH AMERICAN ORCHARDS. By W. H. CHANDLER. Lea & Febiger. Philadelphia. $4.50.

From its unassuming title alone both the English Fruit Grower and Investigator might be inclined to let this book drift by in the flood of Horticultural literature which is washed to these shores from the American Continent. However, all have learnt to expect from the pen of the author of "Fruit Growing" something worth reading, and something of far wider application than he modestly claims through his choice of titles. Whilst it is true that certain chapters deal with sub-tropical and tropical fruits, Apricots, Almonds, Walnuts and Pecans which are not commercially grown under our climatic conditions, even here the attitude from which these problems are dealt with makes the subject very generally instructive.

It would be of great advantage if every fruit grower and investigator in whatever clime could only read the chapter on "How the Best Practices are Learned." Here out of his far reaching experiences of American conditions, Chandler evaluates the experience of growers, the scientifically planned experiments of the field investigator and the application to fruit problems of the fundamental principles of the pure scientist. The grower would become vastly more critical of his impressions, the field investigator far more careful of his field technique and far less rash in drawing deductions therefrom, whilst the scientist studying in the laboratory would make many more excursions into the orchard. After reading Chapter VIII they would all understand one another better.

In such a chastened mood, the author proceeds to muster together all the information which he has managed to collect from all these sources in relation to the important influences of Climate, Variety, Environment, Propagation, and subsequent Management and Handling from the time of planting to the time of dispatching the finished product from the packing shed. One is tempted to turn aside to discuss a hundred theories and practices!

It is like a heart to heart talk between a keen investigator and a practical grower relating their experiences and trying to reconcile their theories, and in these papers the number of subjects raised and the manner of their treatment will surely absorb both. Perhaps the experimenter may be inclined to say that a little more might be claimed for his achievements, and the grower feel a little depressed that there is still such a vast territory to be explored before the methods of his industry can be based on the theories of an exact science, but Chandler has spoken plainly and made it possible for both parties to appreciate such other's contributions and difficulties more fairly.

The scientific background of the book should be every intelligent fruit grower's stock in trade, the practical flavour should afford the atmosphere in which all investigators in fruit production might advantageously carry out their operations. The problems of North American Orcharding have a very wide lesson to proclaim. Finally, no better medicine could be prescribed to every young man who lightly contemplates embarking on the industry as an easy means of livelihood, which does not involve too much brain fatigue!

STATISTICAL METHODS FOR RESEARCH WORKERS. (Third Edition.) By R. A. FISHER, Sc.D., F.R.S. Published by Oliver & Boyd, 33, Paternoster Row, E.C. 1930.

The appearance of the third edition of this volume, provides an opportunity to recommend its contents once more to horticultural workers in field and laboratory.

The reviewer has had occasion of late to examine, in some detail, the literature dealing with the conduct of horticultural experiments in the field.

When the amount of time and labour, which has been expended upon, for instance, fertilizer trials on apple trees, is considered, it is disappointing to observe the comparative poverty of the results. Much of this failure has been due to variation in the material used for experimental purposes. However even when this variation is reduced to a minimum, there comes a point, when the pomologist must look to his methods of plot arrangement, if he is to produce results which will recompense him for his labour and be of value to the fruit growing community.

The author of this book placed his finger on the weakest spot in field experimentation, the fact that experimenters were using statistical methods of analysis, based on the theory of random sampling, to interpret the results from experiments where the samples were not obtained by chance selection. Having drawn attention to this discrepancy, he proceeded to build up methods of plot arrangement, the underlying principles and methods of analysis of which are described in Chapters VII and VIII, which have gone far to revolutionize the art of field experimentation.

Since 1925, when this book was first published, many trials have been laid down using these methods, especially trials of agricultural crops. A number of these trials have given a degree of precision undreamt of by the older experimenters. The adaptation of these methods to horticultural material is merely one step further, and the preliminary returns from a few such trials indicate clearly their probable value to the horticulturist. At the present day it is possible to produce horticultural material of much greater uniformity than was possible a few years ago ; and this fact, in combination with the increased accuracy given by these modern methods of plot experimentation, encourages the hope that the age of successful horticultural field experiments is already begun.

Little has been said in this review about the remainder of this book. Already it is well known to workers in all branches of research. The present edition is somewhat enlarged, as is inevitable, when the advances in biological research call naturally for further assistance from the statistician. In particular the chapter on statistical estimation has been further extended and a generalized form for the series of orthogonal polynomials is included.

WASPS AND HOW TO DESTROY THEM. By S. D. Wrangham, B.A., with a Foreword by W. P. Seabrook. The Pilot Press, 2, Little Essex Street, Strand. 1929. 1s.

This little book which is intended mainly for the fruit grower and gardener gives a clear account of the habits of wasps and the best methods of destroying their nests are discussed in detail.

It is not intended to be a scientific treatise on wasps and therefore should appeal to a large number of readers.

The recognised methods of destroying the nests are given, and many useful tips for carrying out the operation in the field will be welcome to the layman.

The author refers to the use of cyanide of soda as a means of destroying the wasps, and one cannot help feeling that the dangers attached to the use of this poison should have been stressed more fully.

A.M.M.

MODERN FRUIT GROWING. By W. P. Seabrook. Published by Benn Bros. Ltd. 1929. 6s.

This manual first published in 1918 has been entirely re-written by Mr. Seabrook, and now includes twenty-one chapters and an excellent index. In his preface the author apologises for references to his own operations and conditions. The chapters describing various operations on Mr. Seabrook's farms are, however, a model of clear and vigorous writing and should prove invaluable to intending planters. Chapter IV deals with the shape and age of tree at time of planting, and the views expressed on this controversial subject are all the more interesting in view of the source from which they come. Mr. Seabrook recommends the planting of three year old trees on the ground that these represent the survival of the fittest in the nursery row. This should serve to refute the argument not infrequently put forward to the effect that three year old trees are usually those which have been left in the nursery from year to year in the hope that they would make a saleable tree if left there long enough !

It is doubtful whether all will agree with the statement on page 47 with regard to bush fruits to the effect that " three year old bushes are much more generally planted now than one year old ones, and present better value."

Chapter V deals with Stocks. Mr. Seabrook is of the opinion that the irregularity of the size and performance of trees on seedling stocks is " almost negligible provided the trees are comparatively even in size and if they are at least three years old when planted." This might be considered at variance with the findings of some English pomologists, but Mr. Seabrook explains his view by saying that the process of culling in the nursery rows results in trees of very fairly even strength. " Also the scion of the cultivated variety has a levelling effect on the growth and performance of a tree which goes far to counteract any difference there may be in the habits of the stock."

This is indeed a most interesting theory, and one which it is clearly of vital importance to prove or disprove beyond all shadow of doubt. When the author goes on to state with all the emphasis of italics, that " strain of variety is probably of far greater value " than root-stocks one is tempted to hope, in view of all that such a suggestion implies, that Mr. Seabrook may one day be tempted to produce his evidence in support of it.

THE ROOT SYSTEM OF FRUIT TREE SEEDLINGS.

By V. A. KOLESNIKOV.

Kubansky Agricultural Institute, Krasnodar, U.S.S.R.

THIS work was carried out chiefly at the Petrovsky (now Tymiriasevsky) Agricultural Academy, Moscow, during the period 1919-1924, and at the Kubansky Agricultural Institute, Krasnodar, North Caucasus, in 1929.

The plants used were seedlings of the following species :—

Apple : *Malus sylvestris* (Mill.).
M. pumila (Mill.).
M. baccata Maxim.
M. baccata purpurea, and
Antonovka (variety).
Pear : *Pyrus communis L.*
Sour Cherry : Vladimirka (variety),
and also *Pinus sylvestris L.*
and *Picea excelsa Link.*

The problem was the elucidation of the quantitative relationships of root growth.

The plants grown in Moscow were in a porous blackish soil not more than 25 cm. in depth overlying hard clay on a site formerly occupied by a forest.

The seedlings grown in North Caucasus were in a blackish soil, the upper uniformly-coloured dark layer of the soil being to 150 cm. in thickness, the lower being to 230 cm. in depth—a soil of chestnut brown colour.

In the first season's work (1920) the seedlings were transplanted, the main root being shortened, and in the later work (1921, '22, '23, and '29) they were sown 10 cm. apart in rows which were 20 cm. apart. They were accorded the treatment usual for seedlings.

METHOD OF REMOVING ROOTS FROM THE SOIL AND OF TAKING RECORDS.

When the seedlings were young, each was lifted with a ball of soil round the roots and this was removed by washing in a pail of water. With older plants, a trench about 1 metre wide and 1 metre deep was dug across the end of the experimental plot. The seedlings were supported by tying them to a stake and the soil was washed from the roots into the trench by means of a thin jet of water from a pump. In order to wash out three or four seedlings, some fifty to sixty pails of water were required and the process occupied from six to seven hours. At intervals, the water accumulated in the trench was removed, and when the required number of seedlings had been washed out, the trench was emptied of water. Two rows of seedlings were then removed and discarded, a shield placed against the exposed face of soil and the trench filled with fresh soil. On recommencing operations, the shield was removed, two further rows of seedlings discarded and a fresh trench dug prior to the application of the water jet.

The majority of the rootlets are distributed in the upper (in Moscow 20-25 cm. and in Krasnodar 50 cm.) layer of the porous soil which is very easily washed off. The deeper roots are thicker and any loss is soon observed.

Measurements and records were made in the laboratory. The primary root is termed a root of the first order, secondary roots arising from it are of the second order and so on.

The root system, as a whole or in parts, was arranged on a wet cloth and covered with a sheet of glass, after which, all the rootlets were carefully measured. All rootlets above 8 cm. long were measured accurately, and it was found that the shorter ones could be satisfactorily estimated by inspection after some practice. Two hours' work was required to measure 1,000 rootlets and in the course of the research over four seasons, 120 root systems comprising 350,000 separate rootlets were dealt with, the total length of root amounting to 2.5 km. Of apple and pear alone twenty-five root systems were examined and their 250,000 rootlets measured 1.5 km.

In Krasnodar in 1929, twenty-four systems were washed out and examined, the total length of roots being 3099.4 cm. and the number of roots 43,556.

COURSE OF DEVELOPMENT OF THE ROOT SYSTEM

Order of Appearance of Branch Roots

Following seed germination the primary root (first order) grows unbranched to a depth which, depending on soil and other factors, may amount to more than 10 cm. Soon this primary root gives rise to roots of the second order which in turn, after a week or two, produce branches of the third order and so on. In apples and pears, during a growing season of five or six months, roots of eight orders were developed, whilst during the same period the pine developed only five orders.

Table I. represents the results obtained with apple in 1920. These plants were transplanted when two or three leaflets had developed and at the same time the primary root was cut to a length of 3 cm.

This is a common commercial practice designed to produce better branching of the roots.

Exactly similar results were obtained in 1921, when duplicate seedlings were examined at intervals of about a month through the growing season.

Thus by the beginning of May, roots of the second order have appeared, those of the third order being visible by the middle of the month, fourth order at the end of May, sixth at the end of June and eighth by the end of the season.

TABLE I.

Order of Development of Roots of Malus sylvestris Mill., 1920.

Lengths in cm.

Month	May				June			July	August
Date	4	9	19	29	8	18	28	18	27
Height of Plant	2.7	3.5	6.7	9.4	9.6	13.0	22.6	34.0	66.0
Root Depth	3.0	3.0	8.1	10.1	14.1	21.3	24.2	28.0	54.0
Aggregate Length (*a*) and Number (*b*) of Roots of Each Order.									
1 (*a*)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
(*b*)	1	1	1	1	1	1	1	1	1
2 (*a*)	14.5	27.6	41.3	98.2	119.1	134.3	137.4	140.1	214.0
(*b*)	16	15	14	27	24	11	15	9	11
3 (*a*)	—	0.1	20.9	161.6	327.4	680.6	566.2	1246.3	2842.9
(*b*)	—	1	80	260	360	473	440	475	691
4 (*a*)	—	—	—	14.0	137.3	379.8	452.2	2790.3	9754.6
(*b*)	—	—	—	74	497	1193	1200	3283	10567
5 (*a*)	—	—	—	—	0.8	5.1	47.9	1233.8	8364.8
(*b*)	—	—	—	—	5	32	256	3434	20426
6 (*a*)	—	—	—	—	—	—	—	81.2	1744.3
(*b*)	—	—	—	—	—	—	—	333	6206
7 (*a*)	—	—	—	—	—	—	—	2.6	206.9
(*b*)	—	—	—	—	—	—	—	14	541
8 (*a*)	—	—	—	—	—	—	—	—	2.3
(*b*)	—	—	—	—	—	—	—	—	11
Total Length of Roots	17.5	30.7	65.2	276.8	587.6	1202.8	1206.7	5497.3	231328
Total Number of Roots	17	17	95	362	887	1710	1912	7549	38454
Average Length per Root	1.0	1.8	0.7	0.8	0.7	0.7	0.6	0.7	0.6

The increase in number and length of roots of any one order is seen in the horizontal rows.

In Table I. a full season's growth produced 38,454 roots of a total length of 231.3 metres. In the following year the figures were 26,094 and 162.9 metres respectively. The whole of this system is distributed in the upper layer of soil from 42 to 54 cm. deep. The above ground portions of the plants being from 42.5 to 60 cm. high. It is seen from this how thoroughly the soil is permeated by the root system.

THE PROPORTION OF ROOTS OF DIFFERENT ORDERS.

From such data as those in Table I. can be calculated the proportion of roots of different orders which are to be found at different periods. Thus, at the end of May, from 63 per cent. to 76 per cent. of the roots are of the third order. This figure decreases as new roots are formed and by September has reached as low as 11 per cent. by which time the majority of roots present are of the fourth and fifth orders (about 38 per cent. of each).

THE AVERAGE LENGTH OF ROOTS OF DIFFERENT ORDERS.

Table II. shows the average length of roots of each order at different dates. In 1920, second order roots were visible on May 4th and averaged 0.9 cm in length. They increased in length continuously through the season, even when roots of higher orders were developing, and this is also true of roots of all orders. Further, at any one date the average length per root decreases, passing from lower to higher orders.

The same result has been obtained with systems examined in 1921.

TABLE II.

Average Length of Roots of Different Orders at Different Dates.

Roots of Order No.	*M. sylvestris* 1920.					*M. baccata* 1923.			*M. pumila* 1929.		
	May		June	July	Aug.	June	Aug.		June	July	Aug.
	4	29	28	18	27	29	2	23	6	17	14
2	0.9	3.6	9.2	15.5	18.6	2.5	5.3	3.6	1.9	3.8	4.3
3	—	0.6	1.3	2.6	4.1	0.3	0.7	0.9	0.3	0.6	0.6
4	—	0.2	0.4	0.8	0.9	—	0.3	0.6	0.1	0.3	0.2
5	—	—	0.2	0.4	0.4	—	0.1	0.4	—	0.2	0.2
6	—	—	—	0.2	0.3	—	—	0.3	—	—	—
7	—	—	—	0.2	0.4	—	—	0.2	—	—	—
8	—	—	—	—	0.2	—	—	—	—	—	—

DISTRIBUTION OF ROOTS OF EACH ORDER ACCORDING TO LENGTH.

Table III. gives an analysis of the roots of each order of a single tree (1921) according to their length. Similar figures were obtained from two other apples and two pears in 1921, 1922, 1923 and 1929.

TABLE III.

Range in mm.	No. of Roots of Order:							
	1	2	3	4	5	6	7	Total.
1–5	—	6	715	4153	2557	470	6	7907
6–10	—	14	282	1233	680	64	—	2273
11–15	—	10	204	403	190	—	—	807
16–20	—	7	138	118	60	—	—	323
21–25	—	8	142	82	22	—	—	254
26–30	—	5	93	30	5	—	—	133
31–35	—	7	66	31	1	—	—	105
36–40	—	—	44	19	—	—	—	63
41–45	—	2	37	20	—	—	—	59
46–50	—	4	29	14	1	—	—	48
51–55	—	3	20	4	—	—	—	27
56–60	—	2	15	11	—	—	—	28
61–65	—	3	13	8	—	—	—	24
66–70	—	2	8	3	—	—	—	13
71–75	—	4	9	2	—	—	—	15
76–80	—	4	4	3	—	—	—	11
81–85	—	1	6	2	—	—	—	9
86–90	—	—	—	—	—	—	—	—
91–95	—	—	4	3	—	—	—	7
96–100	—	—	1	—	—	—	—	1
100–400	1	13	16	5	—	—	—	35
Total	1	95	1846	6144	3516	534	6	12151

These figures show that the later a root emerges (the higher its order) the less is the maximum length, independently of the number of roots in each order. In all except the two lowest orders, shorter roots are in the majority, more than 50 per cent. of the total roots being from 1-5 mm. long and 90 per cent. are less than 15 mm. long in the higher orders.

When different plants of the same variety are compared, it is found that the average length per root is remarkably constant. The figures in Table I. show that this average is nearly 7 mm. as soon as about 100 roots have been produced. Of similar root systems examined in 1920, two gave an average root length of 7 mm. and the rest 6.0, 6.0, 6.3, 7.6 and 7.7 mm. In the following year, of sixteen systems examined, ten gave an average of 7 mm. and the remainder 6.0, 6.0, 6.2, 6.4, 7.6 and 7.7 mm. In 1922 and 1923 six plants of *M. baccata* gave 6.0 mm. and one gave 5.4, two of sour cherry gave 8 mm. and two of Antonovka apple gave 6 mm. Ten examples of *Pinus* gave 3.5 and two of *Picea* gave 7.7 and 7.8 mm. In 1929 the seedlings of wild apple gave 6.4, 5.9, 4.8, 6.0, 6.2, 6.3, 7.1, 5.6, 7.5, and 7.1 mm., and of wild pear 6.7, 8.5, 7.8, 6.5, 7.1, 7.1, 7.1, 9.2, 7.5, 9.3, 7.9 and 7.0 mm.

These results indicate that the average length of the rootlets is a character which is constant for the species or perhaps the variety.

The regularity of this relationship having been established, the investigation was carried further and separate smaller units of each system were considered. The main root (first order) gives rise to a number of roots of the second order, and each of the latter, together with its subsequent branchings may be considered as a small separate system. One of the apples examined in 1920 had produced fifteen such second order roots and each of these fifteen systems could therefore be treated separately. The average root lengths for these fifteen sub-systems were as follows : 7, 7, 8, 8, 7, 7, 6, 8, 6, 6, 6, 7, 7 and 7 mm. The sub-systems differing from the average all had relatively small numbers of roots and thus by taking a reasonably large sub-system it is possible to obtain an accurate figure for the whole system.

Similar analysis of an apple root system examined in 1921 showed seventeen sub-systems having average root lengths of 5, 7, 5, 7, 8, 7, 6, 6, 7, 6, 6, 7, 8, 8, 8, 9 and 7 mm. The variation was here much greater, as might be expected when the number of roots in some of the sub-systems was small. There is a tendency for roots to be shorter near the soil surface than when they are deeper.

A tree of *M. baccata* recorded in 1922 gave a figure of 6 mm. and its twenty sub-systems all gave averages of either 5 or 6 mm. even though four of these included only from 0.7-2.0 per cent. of the total roots.

The fact that the average length of roots is practically constant throughout the season and can be determined for the whole system by a detailed examination of a small portion (5-10 per cent) is of great value. The possibility of using a sampling method allows of a much greater extension of the investigation for the same amount of labour, providing a representative sample extending to a reasonable depth is taken.

The investigation has demonstrated the regularity of the cycle of root development throughout the season and has shown that these young seedlings do not produce many long roots penetrating great distances. On the contrary, a block of soil 60 cm. deep with a horizontal diameter of 30-40 cm. may have 40,000 separate rootlets and contain 231 metres length of roots which therefore permeate it very effectively.

The depth, length and number of roots no doubt depend upon the variety, soil and environmental conditions.

SUMMARY.

1. A definite order prevails in the development of roots in a season.

2. Small rootlets less than 10 mm. long comprise more than 80 per cent. of the total number present.

3. The average length of roots decreases from roots of the first order to those of the higher orders, but it is less in a system near the surface than in deeper systems.

4. The average length is practically constant in systems of the same variety, and is often constant throughout the season.

5. The average root length of a system can be determined by examination of a small sample.

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THE DYING OFF OF ROOTLETS OF FRUIT TREES.

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THE following observations are concerned with the dying off of portions of the root systems during their first year. They have shown the tendency of rootlets to lose their tips, following which more profuse branching may occur. In addition, an attempt has been made to study quantitatively the dynamics of both the loss of tips and the disappearance of whole rootlets, which has been observed by Duhamel du Monceau, Busgen* and others.†‡

The dying off proceeds simultaneously with the seasonal development of the root system and the two processes have been studied together at the same time on the same plants.

Before proceeding to an analysis of the results, the quantitative phenomena will be discussed.

In effecting the normal distribution in the soil, the developing roots encounter many obstacles, such as decaying plant remains, and in surmounting or penetrating these obstacles, the young roots follow a sinuous course. It is in the region of the sinuosities that the greater part of the lateral roots are disposed.

The branching of a root system is more profuse in the upper 20-25 cm. in the Moscow soil and in the upper 50 cm. in the Krasnodar soil and below this level the roots take advantage of crevices of the soil, plant remains or burrows of insects and animals, especially those of earth worms, as observed by Darwin.

At the end of the deeper roots a number of rootlets are often to be found twisted into a clubbed mass and sometimes several roots are found packed tightly together following straight parallel courses. Tolsky observed that a number of roots are sometimes grouped together in a tunnel where they pass the winter. Lateral rootlets were developed but often did not penetrate the walls of the tunnel, remaining as part of the " clubbed end."

Roots of fruit trees when close together have been observed actually growing into each other forming oblate or ribbon-like structures, in consequence of the shape of the passage through which they pass.

In the absorbing region of the root, a transverse section shows it to consist of a central cylinder of xylem, amounting to one third or one fourth of the total size, surrounded by a layer of "primary bark." As the root lengthens, this primary bark is progressively sloughed off and is replaced by a thin layer of "secondary bark." As a result of this, young roots are thicker at points near their tips than at points further away.

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* *Busgen.* Flora, 1905, 95, 58.

† *Kroemer.* Die Reben und ihre Kultur. Handbuch. 1909.

‡ *Tolsky.* Materiali po isweheniu Kornei, etc., 1905.

QUANTITATIVE OBSERVATIONS.

A. THE DYING OFF OF ROOT-TIPS.

This process takes place rapidly, the tip ceasing to grow, dying and disappearing in a short space of time so that the dead tips themselves are rarely found in the soil.

In all the systems examined in 1920, 1921, 1922, 1923 and some of those of 1924 and 1929, records were taken of all roots of all grades which had lost their tips and it was found that dying off had taken place in roots of all orders except those of the two or three highest orders (the shortest in length).

Some 80-90 per cent. of the plants of *Malus sylvestris* in 1920-1921 had lost the tips of their primary roots. The figure for *M. baccata* was 70 per cent., Antonovka apple, pear and cherry 50 per cent.; pine, 40 per cent.; fir, 100 per cent. and ash, 30 per cent. The figure for *M. pumila*, 1929, was 20 per cent., for *P. communis* 25 per cent. These facts provide an explanation of the opinion of fruit tree raisers that some apples naturallv produce a well branched root system even without having the primary root pruned artificially.

Table I. shows the percentage of roots which had lost their tips at different dates, roots of each order being grouped separately.

TABLE I.

Percentage of Roots of Apple with Dead Tips. M. sylvestris Mill. 1921.

Roots of Order	May 25.	June 9	July 6	Aug. 10.	Sept. 14
	from 4 trees.	from 5 trees.	from 4 trees.	from 2 trees.	from 1 tree.
1	75.0	100.0	50.0	100.0	0
2	6.2	75.3	25.0	50.0	46.0
3	0.4	1.1	2.8	5.2	10.5
4	—	0	0.3	1.5	3.3
5	—	0	0	0.2	1.0
6	—	—	0	0	0.3
7	—	—	—	0	0
8	—	—	—	—	0

The figures show that the percentage is lower in the roots of higher orders than in those of lower orders, and there is a tendency for the figure to increase in any one order from spring to autumn. Similar results were obtained with other apples, pear and cherry in 1920-24 in Moscow, and also in 1929 in Krasnodar.

If the roots are graded according to length as in Table II., the phenomenon is seen more clearly from a different angle.

TABLE II.

Percentages of Dead Tips on Roots of Different Lengths.

Root Length.	% with Dead Tips.			
	Apple.		Pear.	
	1921	1929	1921	1929
1–5	0.3	0.8	1.4	0.8
6–10	2.6	1.3	3.9	1.5
11–15	5.2	2.2	7.4	1.7
16–20	8.7	3.7	8.0	3.9
21–25	8.3	4.0	8.2	1.4
26–30	9.7	6.0	11.1	4.1
31–35	10.5	3.0	11.3	4.0
36–40	16.7	20.0	14.3	7.5

Thus, the longer the roots, the higher is the proportion with dead tips. It has already been shown in an earlier paper (1) that the percentage of longer roots increases in any one order as the season progresses, and also that at any one time, roots of a lower order have a greater average length than those of higher orders and these relationships are reflected in Tables I. and II.

It may be remarked finally that all the roots of a system are liable to lose their tips with the result that new lateral roots are developed from the stumps. The laterals themselves may repeat the process and thus there is a lack of long bare roots, the system being composed of a complete network which thoroughly permeates the medium.

B. THE DYING OFF OF COMPLETE ROOTLETS.

This may occur as a graduated process, the older roots being first denuded of rootlets and the younger ones following in succession, or it may occur through the system simultaneously. The process begins by a colour change to black and the rootlets then disintegrate and easily fall off when handled. In a series of apples examined in 1920 the process was clearly observed. In May and June (see page 199, Table I. of ref. (1)) the average number of second order roots arising from a primary root of 3 cm. in length after pruning at transplanting, was nineteen. Later examinations showed the number to be reduced (July and August, 1920) to between nine and twelve on the same length of primary root.

In view of the regularity of root production which has already been determined (1) a further investigation was made of the frequency of the occurrence of roots of each order upon roots of the next lower order and Table III. shows this relationship throughout the season.

TABLE III.

No. of Lateral Roots Present per cm. of Older Roots. Apple. 1921.

Roots of Order :	No. of Roots of Next Higher Order (per cm.)				
	May 25	June 9	July 6	Aug. 10	Sept. 14
1	3·7	4·3	4·5	4·0	4·0
2	2.0	2.7	3·1	3·4	3·6
3	—	0.8	1.3	2.0	2.6
4	—	0.1	0.5	0.8	1.4
5	—	—	0.2	0.3	0.7
6	—	—	—	0.1	0.3
7	—	—	—	—	0.1

Thus the number of lateral roots per cm. increases as the season progresses, on all roots except the primaries, and at any one date, the number increases with the age of the parent root. Both phenomena apparently result from the fact that when a root is first formed, its absorbing region (i.e. the portion without laterals) is long, relative to total length. As the root extends, however, the absorbing region remains approximately constant and the length of the portion carrying laterals is increased throughout the season. Hence the average number of roots per 1 cm. of length shows an increase during the growing season.

This occurred in 1920-24 in all orders except the first and occasionally in the second, in which a decrease was sometimes found in autumn.

In 1929 figures were obtained for an apple and a pear in the Krasnodar district which fully confirmed the result shown above in Table III. The summer of 1929 was very dry in Krasnodar and the rootlets died off to an abnormal extent. The process which begins in May or June, continues through the autumn and winter into the spring of the following year and is considerably affected by climatic conditions.

Annual examinations of washed out root systems both in Moscow or Krasnodar have shown that the phenomena of denudation of roots could easily be observed by the naked eye. The author found definite and considerable denudation of roots and dying off even of whole small root systems on a parent root system. The observations have been made annually, throughout a season. The process can be easily watched from the qualitative and quantitative standpoints, by the naked eye, but it is rather difficult to express in figures.

Some further evidence as to the extent of the death of roots has been obtained with pear trees. It had been observed that in August, 1920, some 38,500 rootlets had been developed by an apple, but thereafter, although plants of apparently similar vigour were recorded, neither in autumn nor the following spring was any root system found to have so large a number. The question was examined more closely in the case of seventeen root systems of pears which were excavated during the latter part of 1921 and the spring of 1922, the figures for which are given in Table IV.

TABLE IV.

Showing Difference in Numbers of Roots in Autumn and in the following Spring. Pear. 1921-22.

	1921			1922	
	July 23	Aug. 30	Sept. 30	May 17	June 7
No. of Trees	3	4	5	3	2
Height of Plants ..	10.5	14.4	17.0	17.0	17.0
Depth of Roots ..	37.5	49.5	60.0	60.0	73.0
Length of Roots of 2nd Order ..	305.0	616.0	776.0	755.0	865.0
Total No. of Roots ..	3068	7306	8328	7669	8717

It is evident from the figures of height and depth that the trees chosen in autumn and spring were of similar size and the figures for second order roots also show reasonable agreement. In spite of this, the total number of roots decreased over the winter from 8,328 to 7,669, the deficiency having been more than compensated for, as a result of new growth, by June 7th. The winter decrease of 659 roots, represents a loss of nearly 7 metres, since the average length for pear is about 10 mm. This loss occurs chiefly in regions nearer to the stem.

Consequently, in root systems, changes are in progress throughout a season. In spring there is progressive growth of roots and later, many roots die off, not so much near the extreme boundary of the system but mostly in the region which is nearer to the stem.

It may be added that in spring or autumn transplanting of one year old fruit trees, the main roots were found to be bare of lateral rootlets over a length of 10 or 15 cm. while in August they have about four roots per 1 cm. (see page 199, Table I. of ref. (1)). In transplanting older trees it may be observed that the length of bare roots is still greater.

Consequently, as the plant grows older, the process of dying off of roots may proceed downwards (from the lower to the higher orders) and thus the network of small absorbing roots recedes further and further from the stem, embracing more and more fresh regions of soil as it advances.

All the measuring, the descriptions of roots and the preparation of material for 1920-24 were conducted by the author himself.

In 1929 the measurements and descriptions of roots have been made by Miss A. Bibikova (Kubansky Agricultural Institute, Krasnodar) to whom the author's thanks are due.

The author is greatly indebted to Dr. R. C. Knight, East Malling Research Station, Kent, England, for valuable suggestions and criticisms, in the preparation of this and the previous paper, to whom he extends his sincere thanks, but it should be mentioned that his help was not of such a nature that he may be held responsible for any of the errors that will be found.

SUMMARY.

1. The death of root tips occurs throughout the growing season and results in profuse branching.

2. The process occurs more frequently in longer than shorter rootlets and consequently more in roots of the lower (first, second, third and fourth) orders than of the higher (fifth, sixth, seventh and eighth) orders.

3. The death of whole rootlets and even of small sub-systems occurs to a considerable extent over the whole main system, more so near the primary roots than lower down.

4. Such denudation of a root system, proceeding along the main roots from the lower to the higher orders, results in the steady march of the main absorbing portion of the system into fresh layers of soil, a process which may be observed in the course of a single season.

REFERENCE.

(1) *Kolesnikov, V. A.* The Root System of Fruit Tree Seedlings. *Journal of Pomology*, Vol. 8, No. 3.

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ROOTSTOCK AND SCION RELATIONSHIP.

SOME EFFECTS OF SCION VARIETY UPON THE ROOTSTOCK.

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During the early part of the present century the vegetatively propagated rootstocks for fruit trees have been the subject of considerable investigation and experiment. Particular attention has been given to the study of the effects upon tree growth, productivity and fruit quality that may be induced in a scion variety by the use of these various vegetatively propagated rootstocks. The work carried out at the Research Station, East Malling, Kent, has involved the classification and raising of pure lines of these rootstocks for apples, plums, pears and walnuts. The results obtained from this laborious and painstaking work need no comment at this point. They have been put before the public from time to time by the various workers concerned (7). One inevitable result, however, has been to focus attention on the enormous influence which a rootstock may have upon the growth and productivity of trees of which it is an integral part.

In general practice our fruit trees are a composite whole. By the practice of budding or grafting we cause to grow together as a unit two parts which may and often do have very diverse characteristics. It is not surprising, therefore, that some rootstocks should exercise a dwarfing influence upon a scion whereas others are apparently almost without any effect at all. Neither is it surprising that all varieties are not dwarfed equally by the same rootstock. In view of the composite nature of the trees in question and the fact that the above ground parts are the only parts which provide for the manufacture of the elementary photosynthetic organic food products of the plant, it would be most surprising if there were no influence of scion upon the rootstock.

Under normal conditions it is easy to observe and record the growth and behaviour of the aerial parts of a tree, but most difficult to make similar observations upon the root system. Mainly because of this difficulty of observation, effects of scion upon rootstock are but rarely observed and recorded. In their earlier work upon rootstocks Hatton (6) and his fellow workers found certain influences of scion upon rootstock and they stress particularly the quantitative nature of this influence.

Hatton's observations and results cited above are regarded by the present writer as extremely important. Qualitative differences in root growth induced by scion influence may be difficult to detect and establish, but for the present it is agreed that quantitative effects of scion upon rootstock such as Hatton supplies are pertinent to this discussion and have significance. It is probably a matter of time only before some qualitative differences are made evident.

Horticultural literature contains references to phenomena which strongly suggest that in some cases at least there is an influence of scion upon rootstock which is no less evident than that of the more commonly observed rootstock effect upon the scion. Some of these observations are not grounded in carefully controlled experimental evidence, and may on this account be open to serious criticism. Each case must, however, be appraised upon its merits. Whatever may be the ultimate outcome it is considered by the present writer that these references should be drawn together at this time. This appears necessary in view of the attention that is now being given to the fundamental problems of rootstock and scion influences.

It is not intended at this point to present much new data upon this question of the influence of the scion upon the rootstock but rather to gather together that which is already recorded in the literature and present it without prejudice to any future attempted interpretation and discussion.

Lindley (13) in his book, "The Theory and Practice of Horticulture," devotes a short section to the reported cases of a possible influence of scion upon rootstock. He cites cases where by budding yellow variegated Jasmines on to a green variety as rootstock, the latter becomes variegated like the scion. In the absence of definite information and experiment it is possible that this may be a case of an "infectious chlorosis," something perhaps in the nature of the virus diseases of the present day. It cannot therefore be cited as valid evidence of a physiological influence of the scion upon rootstock. A much more definite and direct case cited by Lindley is that of grafting branches of the "wild" on to the "cultivated" olive in order to renew the vigour and vitality of the latter. According to Lindley it is apparently a very common practice in some of the olive growing regions of Italy to graft branches of the wild olive on to the cultivated olive in order to induce fruitfulness in the latter. Old decaying unfruitful olive trees may apparently be easily and completely rejuvenated by this method. The practice is one of great antiquity for it was known to Pliny whom Lindley quotes at considerable length upon the matter.

Julie (11) in 1905 reported a case which he regarded as an effect of scion upon rootstock. He grafted the variety of grape Aramon Rupestris Ganzen with the variety Gumay d'Arcenant. Some time later a shoot came out at least six inches below the graft union. This shoot had leaves like the vinifera (scion) variety and had fruit which was larger and earlier than that of the rupestris stock. In this case there appears to have been a definite influence of the scion upon the stock in both the leaf and fruit characters of the shoot originating on the stock below the graft union.

Heinicke (9) has reported further cases similar in some respects to that of Julie mentioned above. Heinicke draws attention to the influence which the scion leaves of a top grafted apple tree may have upon the type and quality of the apples borne upon the stock part of the tree below the graft union. Heinicke cites the observations of Trowbridge (23) made in 1880. This latter observer found a seedling apple tree which normally bore small green worthless apples and which had some of its branches grafted over to a red striped variety of apple. On the grafted branches of the stock below the union with these top scions the tree bore apples showing all the characteristics of the scion variety, i.e. striped red fruit. The ungrafted branches on the rest of the tree bore the normal green worthless apples characteristic of the stock. Here, then, is a definite influence of scion upon the behaviour of the stock as regards fruit quality and character.

Heinicke attacked this question experimentally (9), and has shown conclusively that such an influence of scion leaves upon the fruit carried by the stock is sometimes exerted. He has shown, for example, that young McIntosh Red apple trees which had been top grafted with Tomkins King produced modified apples on the McIntosh part of the tree below the graft union. The modification was invariably towards the type of apple characteristic of the top scion. Apples borne upon the ungrafted branches of these trees were normal McIntosh fruits. Several other varieties used as scions in a similar way also produced similar results, that is, a modification of the fruit on the branches of the stock which were grafted.

In a number of cases the influence was so marked that pomological experts were not able to identify the apples carried on the McIntosh part of the tree below the grafts as McIntosh fruits. Indeed, some definitely named them by the scion. The influence was indeed very pronounced because not only was the external appearance of the fruit affected but its aroma, its quality and above all its season of ripening. In some cases the date of ripening of these fruits was altered by four-six weeks. This latter influence alone would indicate that the scion has exercised a considerable influence upon the physiological processes taking place in the branch parts of the stock immediately below the graft union.

Heinicke further points out that there are varietal differences in this matter, and that some of the varieties he used as top scions did not cause any appreciable effect upon the stock. This point of varietal difference is in itself most interesting and we shall have occasion to return to it again at a later stage in this review.

Still further evidence of an effect of scion upon stock was given by Noblet (16) in 1906. His experience is in many ways similar to that of Julie and of Heinicke just mentioned. Noblet grafted the variety of pear Mme. Chaudy, by approach on to the variety Buerre Superfin. Some time later a branch which came out from the stock part below the graft union produced fruit similar in form and quality to that produced by the scion. This Noblet regards as a direct effect of scion upon stock.

Following the severe winter of 1890-91 in France, Vard (24) carried out an extensive survey of the resulting damage to crops and vegetation generally. He found that rose stocks which were normally hardy had been killed by the frost where they had been budded with tender varieties of roses. In no case were such top worked rose stock as hardy as were the unworked stocks. Top working had obviously rendered the stocks less hardy than they were in the unworked condition.

Webber (26) also observed the same kind of effect of scion upon rootstock in the citrus trees of California following the severe winter freeze of 1913. Webber found that there were slight differences in the hardiness of lemon tops depending upon whether the trees had lemon or orange trunks, i.e. an effect of rootstock upon scion, but that there was considerable variableness in this matter so that " no positive rule could be stated." It was found that " In some cases there is apparently a definite influence of the scion tops upon the stocks. In one case, in the spring of 1912, a nursery of sour seedlings were budded to Eureka lemons. Many of these buds did not take, so that during the freeze of January, 1913, there were in this nursery at the same elevation and under the same conditions yearling lemon tops on sour stock (buds had been inserted several inches above the ground) alongside sour seedlings. While a slight injury to the foliage was the only harm experienced by the latter, the lemon tops were killed and the frozen wood extended three to four inches down on the sour stock. Similar conditions were found on Pomelo stock while the Pomelo seedlings were scarcely touched."

In further work upon citrus plants Webber (27) found effects of scion upon rootstock other than those reported in his earlier work. He reports that when Navel or Valencia oranges are budded upon the grape fruit as rootstock the grape fruit stock markedly outgrows the scion in diameter. This also occurs, only to a less extent, when Eureka lemons are budded upon grape fruit stock. In the natural unworked condition the growth rates of these citrus varieties are very similar indeed, so that their differential growth rate when the one serves as a rootstock to the other cannot be explained by differences in their normal growth rates. The effect of the scions in this case is to stimulate a more rapid growth in the grape fruit stocks than they are wont to make. Webber also cites the case of budding lemons or sweet orange on to Trifoliate stocks. Normally the Trifoliate stock grows very slowly indeed but when it is used as a stock for lemons or sweet orange it grows so vigorously that it very soon outgrows the scions. Webber points out that this latter case may possibly be explained by the fact that Trifoliate stock is deciduous whereas the lemon and sweet orange are evergreen in habit. However this may be, there is clear indication that in citrus plants at least there are profound influences of a quantitative nature which a scion may and does exert upon its rootstock.

Further evidence of a quantitative effect of scion upon rootstock in citrus plants is supplied by the work of Robertson Brown (4). Brown shows clearly how much may depend upon climate and local factors in rootstock and scion relationships. He found that in India, contrary to American experience, the sour orange is not at all a suitable stock for the sweet orange. In spite of showing in this work that rootstock does affect the growth of the scion, he shows very clearly indeed that the scion also affects the rootstock. Brown gives a photograph of four rootstocks each having supported as scions two different varieties. The influence of scion upon root growth is most outstanding. Brown regards the roots as " altered completely in vigour *and very much altered habit** by the scions they have respectively supported."

Hofman (10) carried out experiments in which he found that the scion may have profound effects upon the longevity of a bean rootstock. He showed that the root system of the Navy bean which normally has a life of about four months could be made to live for several years by grafting on to it a scion of Lima bean. He also quotes cases of an effect of scion upon the hardiness of a stock similar to those reported by Vard (24) and by Webber (26). Whatever may be the ultimate explanation, it appears to be clearly established that a stock may be adversely affected in its hardiness by having supported as a scion variety one which has a lesser degree of hardiness than that of the stock itself.

Sorouer (19) discusses briefly the question of scion influence and cites Couderc who, by questioning over 450 French grape growers, found that the resistance of American grape vine stocks to the attacks of the grape louse, Phylloxera, was profoundly affected by the scion variety which they carried. The general effect seems to have been one of lowered resistance *although it was quite clear that different varieties exercised influences of varying intensity.* Similar questioning among experienced German grape growers revealed the same general conclusion.

A more recently reported case of an influence of scion upon rootstock as affecting disease resistance in the stock is that of Wormall and Grubb (25) in their studies on " Crown Gall in Fruit Trees." After having shown that the various vegetatively propagated Malling type apple rootstocks are subject to attacks of the crown gall organism in varying degrees, they go on to discuss the susceptibility of these stocks to crown gall as affected by the scion variety which they carry. They do not regard the evidence as conclusive but of sufficient merit to warrant further investigation upon similar lines. They found, for example, that the various stocks when worked to Lane's Prince Albert and Worcester Pearmain showed a far greater development of crown gall than did similar stocks worked to the variety Bramley's Seedling. This difference was followed up and was shown in a large number of trees. This suggests strongly that it is a definite influence of the scion upon the susceptibility of the rootstock to attack by this organism.

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* Italics are mine.

Of the varieties they have so far examined in this connection Lord Derby appears to have had the most pronounced influence in that it has rendered all rootstocks upon which it has been worked very susceptible to attacks of crown gall. Lord Derby is followed by Lane's Prince Albert and Early Victoria in order of this effect. Bramley's Seedling, Bismarck Newton Wonder and Stirling Castle on the other hand appear to render the *same* rootstock types more resistant to crown gall. It is also shown by these authors that the influence of Lord Derby scions upon the susceptibility to crown gall which it engenders in a rootstock is correlated with a very high degree of susceptibility to crown gall in the variety itself. In their experience Lord Derby is the most susceptible variety they have handled.

In his recent book on Viticulture, Perold (17) has given considerable evidence and information relevant to the present discussion. This, however, is scattered throughout the text so that his data will be referred to by pages. On page 184 he quotes Teleke for the fact that some varieties of the European grape grow well on all American grape stocks while other varieties thrive with difficulty if at all on any of these stocks. Continuing, he says, "A few years later Couderc published his observation that, in soils rich in lime, many European varieties grafted on one and the same stock answer well whilst others suffer from lime chlorosis ; further, that a certain stock can be used on certain soils only when grafted to certain European varieties." In other words, Couderc finds that some scion varieties in combination with a rootstock will enable this unit to thrive in a limestone soil, whereas the same stock in combination with other scions growing in the same soil quickly become chlorotic and die. Perold, after long experience with grafted vines, has formed the conclusion that "it is more difficult to farm successfully with grafted vines than with ungrafted vines. . . . We have to do not merely with the symbiosis between scion and stock but also with phylloxera which occurs in smaller or larger numbers on all roots of American stocks. Such a thing as a stock that is absolutely immune to Phylloxera we simply do not possess. Hence the life of the grafted vine is continually in an unstable state of equilibrium which is influenced by the treatment of the vine, the soil and the climate."

the habits of the roots to such an extent that they assume the deep rooting and straggling characteristics of the crab stock." Hatton and Amos (6) whilst suggesting that the influence of the scion upon the rootstock is purely quantitative in character, nevertheless, do supply abundant evidence of a marked influence of the scion upon root growth. In the face of the evidence given from Perold's book, that supplied by Hatton and Amos (6) assumes a greater importance than it could do when standing alone.

Hatton and Amos report a quantitative effect of scion upon rootstock. The variety Stirling Castle which only produced a top growth half as heavy as that produced by Bramley Seedling, had only about half as much root. They further showed that some varieties, such as Lord Derby, gave upon all rootstocks used in the experiment, a higher percentage of fibrous roots than the other varieties gave when growing upon similar stocks. Clearly there is an influence of this scion (Lord Derby), upon several rootstocks impelling them all in a uniform direction, namely the production of relatively more fibre to coarse roots. Still more significant are their observations upon the effect of scion variety upon the distribution of roots along the underground portion of the rootstock. This is given as follows: " Secondly, there is the question of depth below ground level of the chief part of the root development as affected by the scion. The length of stock below ground was, for the purpose of analysis, divided into two equal portions (roughly 10.0 cm. each). Very fortunately the length below ground proved remarkably regular. Generally speaking, by far the greatest bulk of roots came from the bottom area (from 10 to 20 cm. below ground level), but within the whole range of the underground stem, the area of main root development was exceedingly variable. There was, however, one striking exception where, with greater uniformity than usual, more than half the roots came from the top area. This was in the case of Grenadier, which showed this characteristic strikingly when budded upon Type VI. Whether this is a consistent characteristic, further examination will show." Whatever may be the ultimate interpretation put upon these observations they are corroborative of the other results already reported in this paper and form a valuable addition to our knowledge.

One of the founders of scientific horticulture in America, Bailey, in his book on nursery practice (1) devotes a short section to the subject at present under review. " It is indisputable," he says, " that there is a great difference in the root system between the ordinary budded tree and the ordinary root grafted tree. The roots of the root grafted tree as it leaves the nursery are comparatively shallow and horizontal and are generally prongy and strongly developed on one side or other of the tree. *It is well known of course that different varieties of apples develop a different root system in the nursery row, but the same variety has a very different root development when propagated by budding and by*

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* Italics mine.

*common root grafting.** The writer has seen this difference so uniformally for so many years and upon such an extent and variety of stock both east and west that he has no hesitation in positively affirming that as generally grown, the root system of budded trees is unlike that of root grafted trees." Bailey then goes on to explain this difference which he regards as being due to a different method of treatment. Attention is drawn at this point to two statements made by Bailey. He is first of all quite clear and definite that different varieties of apples develop a different root system in the nursery row. This statement can be substantiated by reference to a number of writers upon nursery practice and is of course very well known to American nurserymen. Its occurrence will be noted several times later in this paper. It is regarded as a positive statement of an effect of scion upon the kind and character of the root system. The other statement concerns the difference between trees propagated by budding and by root grafting. This is a most interesting question and raises the problem of the nature of rootstock influence. It is towards an understanding of this latter problem that work is now being initiated and to which the present review of scion influences is a preliminary.

Professor Barker (5) in his early studies on the root development of apple trees observed what has been subsequently noted on several occasions at Long Ashton, that a scion variety has a marked influence upon the vigour and amount of an apple root system. He says that " The individual sets of trees so far lifted for examination lend support to the view that the scion variety exercises a material influence upon the root system. For example, the relatively vigorous Allington Pippin has produced trees with roots coarse and lacking in fine fibre as compared with those resulting from the weaker Stirling Castle, the English Broadleaf Paradise being the rootstock type used in both cases."

Mr. E. S. Welch who is the president and manager of a large nursery at Shenandoah, Iowa, and who there propagates upwards of four million apple trees a year by root grafting records his experience as follows (28). " As a rule each part of the combined plant, the stock and scion, maintains its individuality. There are certain cases, however, in which the scion seems to partake of the nature of the stock and others in which the stock partakes of the nature of the scion. There are some varieties of apples and pears which when worked upon seedling root will change the habit of growth of that root. Examples are Northern Spy and Whitney Crab, which when grafted on a root of unknown parentage, tend to make that root grow very deep in the soil. All these instances seem to be special cases or exceptions to the general rule that each part maintains its individuality." The present writer, in company with Prof. R. H. Roberts, had the pleasure in spring, 1927, of going over this nursery and Mr. Welch was kind enough to provide a small gang of men with instructions to lift such trees as we might desire. It was then established to our complete satisfaction that a number of varieties had an outstanding influence upon root growth (22).

Shaw (20) in 1915 also investigated this question of an influence of scion upon rootstock. He figures several varieties which he thinks show this effect most clearly. He regards the influence as quantitative in character but " obvious and persistent," and believes " that the size or stoutness of the main branches (of the tree) is positively correlated with the size of the main roots and the angle of the branches with the angle of the main roots and the axis of the tree. In many individual cases this correlation is obscure yet careful observation with large numbers of trees will reveal it."

Gardner, Bradford and Hooker (30) devote a short section of their book on fruit growing to a discussion of the possible influence of scion upon rootstock and cite a number of cases gathered from horticultural literature. Many of these cases are not here reviewed and the reader should consult them for further evidence along this line of thought. The above authors think that from the cases cited and whatever the cause " there is apparently sufficient evidence to warrant the statement that in some cases the scion does influence the stock." Two cases given by Gardner, Bradford and Hooker are quoted here in order to strengthen the present section. Murneek (15) is quoted as follows. " Upright growing varieties of apples of the Russian type, for instance, will form a correspondingly deep growing root system, while those of the winesap type will be flat and shallow. This can be extended even to particular varieties. The Red Astrakan, Oldenburgh and Fameuse for example form each a characteristic root system of its own." These observations confirm those of Bailey, Swarbrick and Roberts, and of others down to the finest details.

Waugh (29) is also quoted at some length by Gardner, Bradford and Hooker as follows. " Stoddard tops (plum) seem to give some of the (characteristic) curved tap root character of the Americanas to all the stocks on which they grow. . . . One interesting point was in the way in which Stoddard tops induced a conspicuous branching of the root system when worked on to peach. With other varieties the peach (as a stock) gave almost always a clean unbranched tap root. . . . Newman (plum) seemed to influence all stocks in the way of giving off more secondary roots." In the following year Waugh reported that he could not observe the effects of scion upon rootstock which he found so markedly present the previous season.

It has been found on several occasions that root grafted trees are more hardy than budded trees of the same variety. This has been recently pointed out by Brierley (2) and by Maney (14) both working independently. Both these authors, however, regard the superior performance of the root grafted trees as due to the fact that with such trees the unions are placed below ground level when the tree is planted. Maney, however, does suggest that the superior hardiness of root grafted trees may be due to a scion influence for he says that " Practical experience has shown that grafted trees are hardier than budded trees but the difference is the result of soil protection to the seedling or to scion influence rather than to the production of scion roots." Bradford and Cardwell (3) show clearly that certain varieties are hardy under Michigan conditions whereas others are not. Their data are difficult to understand except upon the basis of an influence of scion upon rootstock unless it can be proved that these varieties throw roots from the scion stem and that these roots are more hardy than the original seedling roots.

The possibility of such trees being scion rooted in the accepted sense of the term cannot be ignored, but the difficulty of obtaining scion rooted fruit trees of most varieties is notorious. The experience of Maney quoted above is a case in point. In any case, it is difficult to accept at its face value the explanation offered for the superior hardiness of root grafted trees, namely, that the hardiness is due to soil protection given to the graft union, because in places where hardiness is a real problem the ground is frozen to a greater depth than that of the graft union, unless trees are planted at excessive depths. In view of the demonstrated effects that grape varieties have in rendering grapestocks more resistant to lime chlorosis and to attacks by Phylloxera it is not difficult to accept the same principle as applying in greater or less measure to these effects of apple scions upon their rootstocks in relation to increased hardiness.

The influence of the scion upon rootstock in apples has been recently emphasized by Swarbrick and Roberts (22). An extensive examination of a large number of commercially raised apple trees was carried out in the Middle West of the United States of America. It was found that in trees propagated by bench grafting there was a marked effect of scion upon root character, but that this effect was less, or in some cases non-existent, in the budded or high worked trees examined. It was furthermore observed that when the very low budded trees were selected from amongst the large mass of trees propagated by budding, their root systems approached more and more towards the " type " common for the variety in question when propagated by bench grafting. It is interesting that without previous knowledge of the work of Bailey (1) or Murneek (15) these workers' observations were fully confirmed. Winesap was invariably a shallow horizontally sparse rooted variety and Red Astrakan coarse rooted with a strong downward tendency, notwithstanding the fact that the same miscellaneous seedling root pieces were used as nurse roots in all cases. The illustrations given by Swarbrick and Roberts (22) should be compared with the descriptions supplied by Bailey (1), Shaw (20) and Murneek (15). The agreement is quite convincing.

These observations made upon such large quantities of commercially raised apple trees led Swarbrick and Roberts to the idea that the stem of the rootstock, whether it be of seedling or of clonal origin was a most important part of the rootstock proper. It is possible that this stem piece may have as much influence in determining what is known as "rootstock influence" as the actual absorbing root system. It was suggested that a large amount of the uniformity obtained by the use of vegetatively propagated rootstocks was in the first place due to selection, and in the second to the use—in effect—of a uniform intermediate stem piece. It should follow therefore that greater uniformity of tree growth and performance would be obtained by eliminating such stem pieces when grafting seedlings. The observed greater uniformity of root grafted trees as compared with budded trees worked on to seedling roots is probably to be explained on this basis. Greater uniformity should also follow double working, particularly if the first working takes the form of bench grafting on to root pieces.

While the above paper was in the press two studies bearing on the same subject were published from the Research Station, at East Malling, Kent. Knight (12) found by experiment that the stem piece of a rootstock was an important item in the ultimate effect of rootstock upon scion. He found that a stem piece of a dwarfing stock when inserted upon a vigorous rootstock and then worked to a scion variety produced a dwarf tree. Knight, however, still regards the actual root system as being in a large measure the determining factor in rootstock influence. The difficulty of evolving a satisfactory technique for low working and at the same time preventing scion rooting prevented a complete establishment of some of the points, but the work is being continued. In the same report as the work of Knight just quoted Grubb (31) published his results upon the double working of pears. By using a common rootstock and a common scion variety, but with various varieties used as intermediate stem pieces, Grubb found that there were considerable variations in the growth and behaviour of the scion. Quite clearly in these cases this effect had been produced by or resulted from the intermediate stem piece. He concludes that there is every reason to think that the variety used as intermediate scion does have considerable influence upon the vigour of the resulting trees. He also points out that a vigorous variety when used as an intermediate will not always impart vigour to the scion. Grubb also states that where dwarfing of a top scion takes place, it is not due to bad unions because the trees are healthy and show no signs of death.

It was not intended to introduce any new data or observation upon this matter, but during the gale of November 15th-16th, 1928, there occurred a remarkable demonstration of an effect of scion upon root growth. A large manurial plot which is being conducted at Long Ashton by Mr. Wallace is planted with two varieties of apples, namely, Allington Pippin and King Edward VII. The plot contains 182 trees of King Edward VII and 156 trees of Allington Pippin. They are interplanted so that there is a uniform distribution over the whole plot. The superior number of King Edwards is due to the fact that this variety is employed in the buffer rows between the plots. These trees are all seven years old from planting and growing upon a uniform vegetatively propagated rootstock, Malling Type II. It has been observed repeatedly since the plot was established that although upon a uniform rootstock the King Edward VII. trees while growing normally had comparatively little roothold. The majority of these trees have been in constant need of staking, whereas of the Allington Pippin trees only a few had to be staked. On the morning of November 16th, 1928, following the previous day's gale there were forty-three King Edward trees blown completely over, and another twenty were leaning at an angle of 45° or more. There were many more leaning more or less, and it was found upon detailed analysis that not more than 5 per cent. of the trees of this variety but were appreciably moved. Thus, at least 90 per cent. of these trees were blown over to a greater or less extent. In contrast to this, not a single Allington Pippin tree had been moved. It is pointed out that the Edward trees were distributed all over the plot and the trees on the leeward side suffered equally as much as those on the windward. The Edward trees were carrying a little foliage still whereas the Allingtons were not, but the Allingtons although about a foot less in height had by far the larger tree spread. Furthermore, the Allingtons carried a heavy crop in 1928 whereas the Edwards did not. The odds therefore ought to be in favour of the Allingtons suffering more than the Edwards, but this was not so. Nothing is yet known about the root systems of these two sets of trees, but it is perfectly clear that they had very different degrees of root-hold. However explained, this great difference in root-hold is undoubtedly to be attributed to an effect of scion upon the development of the rootstock as affecting its hold upon the ground.

The most recent and in some ways the most decisive piece of evidence of an effect of scion upon rootstock has been given by Haas and Halma (8). They have worked upon the mineral constituents of the bark of citrus trees taking this as a basis for study because they have previously shown that there are certain fundamental differences in physiological and chemical properties between the various citrus varieties commonly combined into a commercial citrus fruit tree. Bark was analysed from immediately above and below the graft union. They show certain chemical differences between the various citrus species growing naturally. Soluble magnesium in the ash is taken as an indicator, because it is high in grape fruit and sweet orange, but low in the lemon and sour orange tree. They then show that "the amount of soluble magnesium as a percentage of dry matter, or of the soluble ash, depends upon the position which the variety occupies on the budded tree; for where the sweet orange served as scion its soluble magnesium content was considerably higher than when it served as a stock for the lemon scion." "It appears," say these authors, "that the scion species or variety influences the amount of soluble magnesium in the bark of the stock." They show that trees with a lemon scion have average rather low uniform values in both stock and scion for soluble magnesium as a percentage of the dry matter regardless of the fact that four different rootstocks are used. If Valencia or grape fruit is the scion these values are much higher, not only in the scion but also in the stocks. The same type of sour orange which served as a stock for the lemon scion shows a higher magnesium content when instead of a lemon scion it had a Marsh grape fruit or Valencia orange scion. The values for the bark of unbudded sour orange or rough lemon are not much changed by budding on to them either lemon or grape fruit.

A clear case of the dominance exerted by the scion as far as soluble magnesium is concerned is seen in trees which were originally Marsh grape fruit on sweet orange stocks but which were later worked to Eureka lemon. In this case the values for the grape fruit intermediate part as well as for the sweet orange stock are low and are approximately the same as for the lemon scion. Other trees which were not top worked, hence retained their original grape fruit heads, show values for both scion and stock which were considerably higher than those of the top worked trees. In other words the replacement of the original grape fruit top by the lemon scion exerted a profound influence on both the original scion part and the original stock. Therefore, as far as soluble magnesium is concerned there appears to be no very marked influence of rootstock upon scion, but that the scion has profound effects upon the stock.

It would be unwise to venture too much upon this work but it does suggest that the scion may have influences upon rootstocks which are as yet not detected or even conceived. In order to be important and significant these effects need not be of the gross order such as we observe for example when we graft a variety upon a very much dwarfing rootstock. Small chemical differences such as that cited above may be very important in the matter of disease resistance.

It is again stressed, however, that the grafted tree is a symbiotic unit and that there is every reason to suppose that there are mutual actions and reactions of scion on stock and vice versa. Depending entirely upon the ultimate aim and outlook of the observer these actions and reactions will be differently regarded. To some the effects of rootstock upon scion may be all important while to others the reverse may be equally true. But for an elucidation of the purely physiological problem it is essential that *all* these reactions should be considered and given each its due and proper place.

The object of presenting this paper in its present form is to draw together such cases of an influence of scion upon rootstock as have been gathered together by the present writer in his somewhat limited reading in horticultural literature. There are, no doubt, many others of which he would be glad to hear from interested readers. The manifest effects of rootstock upon scion have been clearly stated by Hatton and his fellow workers from their valuable work at East Malling. The existence of a reciprocal influence is in the writer's opinion critically and completely established by the evidence presented herein. In any future attempt to elucidate and understand the nature of rootstock influence it must necessarily be borne in mind that what we are investigating is a symbiotic unit, or organism made up of two parts originally separate and distinct in function and behaviour which are now working together as a whole and that they do have reciprocal relationships, which may reach far deeper than we at present suspect.

The establishment of this reciprocal effect of scion upon rootstock is quite as important if not so immediately applicable as the effect of rootstock upon scion which has been so largely brought to our notice by the work of Hatton and his fellow workers. In the grape industry it was shown that in limestone soils certain varieties would render certain rootstocks less susceptible to lime chlorosis. The possibility of double working immediately suggests itself to the mind. Such a reciprocal influence of scion upon rootstock also becomes important in places like Canada where hardiness is a prime consideration and in parts of Australia and New Zealand where soil conditions are a limiting factor. It may also become important in the cultivation of tropical plants such as the rubber tree.

The simple truth is that as yet we do not know how a rootstock can and does influence the growth of the scion, or how in a reciprocal way, the scion can and does influence the growth, hardiness, disease resistance and depth of rooting of the rootstock. The main facts however would appear to be fairly well established. Experiment and observation have shown that a stem piece between a scion and an absorbing root system may exert an influence which masks and outweighs that of the absorbing root system. Furthermore, a number of points which have hitherto been urged as disadvantages against the use of seedling rootstocks have received considerable elucidation and it is now possible to obtain very uniform material with a miscellaneous seedling basis. Without for a moment under estimating the importance or interest of the established effects of rootstock upon the growth and behaviour of the scion emphasis at this point is placed upon its reciprocal, the influence of scion upon rootstock.

A brief consideration of the implications of the observations recently recorded by Knight (12), Grubb (3) and Swarbrick and Roberts (22) suggests that a vegetatively propagated rootstock and a seedling which is high budded are both complicated physiological units. In any case, they involve the relation of stem to root, a physiological relationship about which little is known. But further, the vegetatively propagated rootstock has problems of its own which do not arise in the seedling in that the former is a rooted stem ; it is a stem plus roots. It is suggested that there may be differences in behaviour between the root systems in these two cases. Under the circumstances, therefore, an effect of scion upon the root system of a vegetatively propagated rootstock, might be less likely to be observed. This may no doubt account for the difficulty that Hatton has encountered in finding it in such material. The use of seedling rootstocks where the roots only are bench grafted reduces the complication to a minimum and eliminates all stem influence but that of the scion itself. It is along these lines that the next step in the elucidation of our problem may lie.

The observations and reports given in this paper are presented without criticism except that involved in the selection of matter and the elimination of such cases as are considered doubtful. Neither is an explanation or working hypothesis offered at this point. It is hoped that attention may be drawn to this phase of the work upon the relations of rootstock and scion. It is stressed that there is no validity in the *a priori* assumption that the use of miscellaneous seedlings will give miscellaneous results. The result obtained seems to depend very largely upon the method of propagation and upon subsequent cultural practice, just as the uniformity of trees upon vegetative stocks seems to depend so largely upon the careful selection of uniform sized stocks for planting out and upon careful subsequent cultural practice.

Progress in the development of our knowledge of the fundamental reactions, conditions and factors involved in the inter-relations of rootstock and scion is necessarily slow. The problems of propagation are not amongst the most simple of these that immediately confront the experimental horticulturalist. For commercial and experimental purposes the claims of the seedling rootstock deserve the same systematic attention and investigation that is being given to the vegetatively propagated rootstocks. The solution of these problems will undoubtedly throw much light on this most interesting question of rootstock and scion inter-relationship.

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THE INCIDENCE AND CONTROL OF APPLE SCAB AND APPLE MILDEW AT EAST MALLING.*

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INTRODUCTION.

The investigation described in this paper is a continuation of work carried on for one year by Miss A. M. Frampton, the results of which were published in 1929 (3).

Much work has been done in the past and much has been written on the methods of controlling Scab and Mildew of the Apple, but very conflicting results have been obtained by different investigators. Similar spraying schemes have given very variable results, and while Bordeaux mixture is recommended by some writers, lime-sulphur is advocated by others, particularly against Scab. Examples of the danger of laying down hard and fast rules for spraying against Scab, and of placing reliance in a given schedule as a universal control measure are many, and are frequently met with in practice. The same variety of apple appears to differ in its response to a given spray treatment even in localities within the same county; a spray that is quite harmless to a variety in one district may cause damage in another. It is not claimed for the present contribution that it shows how this difficulty can be overcome, but efforts have been made to sift out some of the factors which bring about the confusing results mentioned above, and to show why a single spraying programme does not, and cannot logically give the same result under different conditions.

Many of the factors such as spraying machinery, amount of spray applied, delivery pressure, etc., have not been dealt with as the limited scope of the work has not permitted of investigation along all these lines. Special emphasis is laid, however, on such causes of variability in control measures as the condition of the trees, their "build-up" as affected by rootstock, the manurial treatment applied, the time of application of sprays and the reactions of the trees to different climatic conditions, this last being referred to as the seasonal factor.

It is thus evident that what is stated here in regard to the control measures that have given the best results must be taken merely as an indication of what happens on trees of known history and controlled treatment under conditions as they occur at East Malling. It is not the purpose of this contribution to recommend the measures unconditionally, as being certain to give the most

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* This investigation has been carried on with the aid of a special research grant from the Ministry of Agriculture and Fisheries, extending over the three year period from October 1926 to September 1929.

successful results in all cases. Individual cases have to be considered according to their special circumstances, but an elucidation of the factors likely to cause variable results will form a serviceable basis on which to consider treatment to suit these individual cases.

PART I.* APPLE SCAB.

I. Spraying Experiments.

The plot of trees devoted to the experiments was originally used for a trial of rootstocks. There are 288 trees ; 160 are Cox's Orange Pippin, chosen because of its special susceptibility to Scab and Mildew ; the remaining 128 are Stirling Castle, chosen for its susceptibility to Mildew. All are worked on various rootstocks as classified at East Malling. While Stirling Castle has given few data on Scab, owing to the slight amount of infection it has shown, it has proved very valuable as an indicator of the relative amounts of damage done by sulphur-containing sprays, and reference will be made to this later.

The two varieties are planted in alternate rows running due north and south, and all treatment, apart from spraying, has been as uniform as possible. The number of trees of each variety on the same rootstock is generally sixteen, but in some cases it is eight only. Each experiment included certain control trees, i.e., trees sprayed either with an insecticide or a spreader only, or left unsprayed ; and these were chosen so that they were scattered among the treated trees. Where there were sixteen trees on the same variety of rootstock, five were sprayed with one fungicide and five with another ; the remaining six were controls.

The spray fluids were mixed or dissolved in small quantities of water in the laboratory, and were diluted to the required strengths in the field. They were applied by means of hand-pumped knapsack spraying machines ; a single nozzle was used on each, while the pressure was approximately 60 lb. per square inch. Every endeavour was made to observe the strictest accuracy in diluting the sprays, and all the vessels used were thoroughly washed immediately after use. The applications were as uniform as possible, efforts being made to provide a film of spray on the leaves with a minimum of "drip." Large hessian screens were held around each tree during application to prevent spray drift from reaching adjacent trees. Up to the present the trees have been of a convenient size so that all necessary precautions could be exercised fully.

Weather conditions at the times of spraying were noted, and reference to them and to the meteorological records obtained independently at this Station will be made as opportunity arises.

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* Part II. (Apple Mildew) and Part III. (Spray Injury) will appear in a future publication.

SPRAYS USED.

1. *Bordeaux Mixture.*

Pre-blossom. 8 lb. copper sulphate.
8 lb. quicklime.
100 gallons water.

Post-blossom. As above, but 25 lb. quicklime instead of 8 lb. (" excess lime ").

In 1929, 12 lb. of hydrated lime was substituted for 8 lb. quicklime per 100 gallons both before and after blossoming. The disastrous results of this change will be alluded to later.

2. *Lime-Sulphur Solution.* (Specific Gravity 1.3).

Pre-blossom. 1 in 30.
Post-blossom. 1 in 100.

Lead arsenate paste was incorporated with these sprays at the rate of 4 lb. per 100 gallons before blossoming and 3 lb. per 100 gallons after blossoming to avoid complications due to caterpillar attacks. The control trees were sprayed with lead arsenate only.

3. *Lime-Sulphur Solution.*

Post-blossom strength 1 in 150, together with " spray " gelatine, 1 lb. per 100 gallons, as spreader.

4. *Colloidal Sulphur.*

Post-blossom strength 4 lb. to 100 gallons. Gelatine at the above rate was used in this experiment also.

Times of Application.—The pre-blossom application was made in the " pink bud " stage, i.e. when individual flowers were well separated in the trusses, but before they had opened.

The first post-blossom application was made when nearly all the petals had fallen, while the second was made about three weeks later.

The experiments were planned to compare the value of a pre-blossom application with that of two post-blossom applications and with that of three applications, one pre- and two post-blossom.

ARRANGEMENT OF TREES ACCORDING TO TREATMENT (Cox's Orange Pippin.)

Expt. I. Trees on stocks, I., II., IX. and XVI. received a single application (pre-blossom) of Bordeaux mixture and arsenate, or of lime-sulphur and arsenate. The six control trees were sprayed with arsenate only.

Expt. II. Trees on stocks III. and XV. received three applications of the same two fungicides, one pre- and two post-blossom. The control trees were sprayed with arsenate only.

Expt. III. Trees on stock IV. received the same three applications of Bordeaux mixture and lime-sulphur but without arsenate, to see whether lead arsenate affects their fungicidal value. The control trees were not sprayed.

Expt. IV. Trees on stocks V. and XIII. received only two, post-blossom, applications of Bordeaux mixture and arsenate, or of lime-sulphur and arsenate The control trees were sprayed with arsenate only.

Expt. V. Trees on stocks VI. and X. received two post-blossom applications only, lime-sulphur, 1 in 150, being compared with colloidal sulphur, 0.4 per cent., gelatine being added in each case. The control trees were sprayed with gelatine only.

RESULTS OF TREATMENTS.

Before discussing the results of the various methods of treatment on the amount of Scab on twigs, leaves and fruits, it will be necessary in each case to explain how the effects were measured.

1. *Method of Estimation of Scab on Young Shoots.*

The method of estimation described below enables the area of Scab on the young shoots to be expressed in comparable figures, and thus the control of Scab by the different sprays can be readily gauged.

All the trees have been pruned uniformly each winter in such a way that approximately the same proportion of wood is removed from each. This is essential in order that the spraying results may be strictly comparable with each other, but a definite attempt was made to strike a compromise in pruning suitably for both the very weak-growing and the very strong-growing trees. During the winter of 1926-27 the total current year's wood growth was obtained for each tree, and the amount of Scab was estimated both on the prunings and on the current year's wood remaining on the tree. The uninterrupted length of Scab completely covering one half of the surface of each twig (i.e., that half visible with the eye vertically above the horizontally lying twig) was measured.

Scattered scab lesions were combined into uninterrupted lengths, this becoming quite simple with practice. The length of current year's wood was used as a means of standardizing the amount of Scab with the size of the tree. The final " Scab equivalent " for a tree was obtained by adding the lengths of Scab on its current year's wood and making this the numerator of a fraction, the denominator of which was the total length of current year's wood. Each fraction so obtained was multiplied by a constant number, viz. 1,000, to avoid decimals ; and the final figure, though having no intrinsic value, was a means of comparison between the amounts of Scab on the current year's wood of any two or more trees in the experiment.

For example, total length of Scab on current year's wood =20 cm. ; total length of current year's wood =2,000 cm. ; " Scab equivalent " for tree = $\frac{20 \times 1{,}000}{2{,}000} = 10$.

During the following winter, time for such laborious work was not available, hence the amount of Scab remaining on the trees after pruning was neglected. The method of estimation was the same, but the numerator of the fraction was the length of Scab on the current year's prunings × 1,000, and the denominator was the length of the prunings.

During the winter of 1928-29 it was necessary to curtail the method of of estimation further, as the trees were then producing so much more new growth. A " category " method was therefore evolved. Scabbed twigs were selected to represent the maximum area of Scab in a given category, each such area being as nearly as possible twice that in the category next below it. Thus, if the first category was represented by the figure 1, the next would be 2, the next 4, and so on. All pruned twigs from each tree were then arranged by inspection into categories. The method of determining the " Scab equivalent " of the tree was as follows : The number of twigs in each category was found and multiplied by the category figure. The products were added and gave a sum which formed the numerator of a fraction, the denominator of which was the weight of prunings, weight being chosen as being probably the most accurate rapid method of representing the total surface of the twigs. This fraction was then multiplied by a constant number as before. The result was the " Scab equivalent " of the tree as representing the amount of infection on the young, pruned wood. The following is an example worked out from figures obtained for one tree.

(a) Category figures	O.	I.	II.	IV.	VIII.	XVI.	XXXII.
(b) No. of shoots per category ..	167	68	11	16	12	13	0
Product of a × b =	0	68	22	64	96	208	0

Sum of Products =458.

Weight of prunings =52 ounces.

" Scab equivalent " $= \frac{458 \times 100}{52} = 881$ (to nearest whole number).

In the tables of results here presented the following symbols are used :—

B.M. =Bordeaux mixture. L-S. =Lime-sulphur. A. =Lead arsenate.

G. =Gelatine. C.S. =Colloidal sulphur.

The results for trees on *all* rootstocks are not given ; those not included, however, conform, in general, to those tabulated.

Many of the results in the tables have been subject to statistical analysis by Mr. T. N. Hoblyn, and the more pronounced differences in the figures have proved to be significant. Owing to an insufficient number of units, and to variation in the figures upon which the averages are based, the smaller differences must, in many cases, be regarded as not significant; they provide no more than indications which may prove of value in future work.

TABLE I.

Control of Scab on Young Shoots.

Variety—Cox's Orange Pippin.

Spray Treatment.	Stock.	No. of trees.	Average Scab equivalent.		
			1926	1927	1928
Experiment I.:					
B.M. + A. 1 pre-blossom	I.	5	51	55	231
L.-S. + A. ,,		5	36	26	78
Control A. ,,		6	154	64	1000
B.M. + A. ,,	II.	5	78	16	127
L.-S. + A. ,,		5	115	40	131
Control A. ,,		6	191	23	322
Experiment IV.:					
B.M. + A. 2 post-blossom	XIII.	5	1	0	5
L.-S. + A. ,,		5	7	0	30
Control A. ,,		6	52	9	133
Experiment II.:					
B.M. + A. 1 pre- and 2 post-blossom	III.	5	0	1	0
L.-S. + A. ,, ,,		5	0	1	30
Control A. ,, ,,		6	34	11	503
Experiment V.:					
L.-S. 1-150) + G. 2 post-blossom	X.	5	34	3	117
C.S. + G. ,,		5	35	6	43
Control G. ,,		5	130	14	456

The above table shows the results obtained from the main four experiments referred to on a previous page (231). In the pre-blossom sprayed group (Expt. I.) it will be noted that both fungicides gave good control in 1926 but not in 1927, when the amount of Scab on the control trees was surprisingly little, even allowing for the fact that the infection was estimated only on the prunings in that year. Though the summer of 1927 would generally be regarded as a very wet one, the critical period for Scab development (during and immediately after blossoming time) was very fine and warm, and the disease did not have a good chance of rapid development in the early stages of growth.

Owing to high individual variation in the amount of Scab on the twigs of the control trees in 1928, the figures for this year must be regarded as not significant, though they are strongly suggestive.

Some preliminary observations have been made on the time of dispersal of Scab spores (*conidia*) from the pustules on the young wood of the previous year. In 1928, viable spores were found in lesions on the young wood of a control tree of Cox's Orange Pippin on No. IV. rootstock on January 17th. Several scabbed Cox trees in pots were sprayed at that time with various winter washes, but at the "pink bud" stage it was observed that fresh splits in the bark had occurred close to the original lesions, and viable spores were freely being produced while the winter washes still coated the bark.

Sections of some of the lesions were cut and stained in cotton blue, when it became quite evident that the lesion was not a single "pad" of mycelium, but was made up of layers of pads, separated from each other by corky tissue. The outermost pad liberates its spores first, quite early in the year, and then becomes dry and hard. It is followed later on in turn by the two subjacent pads and these split the bark laterally to the primary one and liberate their spores later in the year. This succession in the production of spores continues for many weeks, but the spores liberated in January, February and March have no leaves or blossoms to infect, and are therefore not a source of danger at that period.

Though this successional production of spores appears to be an argument in favour of the application of a spray previous to the "pink bud" stage (possibly in the "green tip" stage), such an application has not been found necessary at East Malling.

Scabbed leaves were collected in the autumn and put on the ground in a wire cage in the plantation, where they remained under natural conditions throughout the winter. Perithecia (*Venturia* stage) developed in the following spring and produced the first ripe ascospores approximately when the majority of apple varieties were in the "pink bud" stage. These observations were made during three consecutive years, namely 1927, 1928 and 1929.

The figures indicate that the effect of spraying was not necessarily similar on trees of the same variety on different rootstocks. Bordeaux mixture was less efficient than lime-sulphur on trees on No. I. rootstock, the reverse holding good for trees on stock No. II.

Better control of Scab on the shoots was given by two post-blossom applications of Bordeaux mixture or of lime-sulphur (Expt. IV). than by one pre-blossom application alone. Spraying against Scab is primarily a protective measure, and when the pre-blossom application is made, the new shoots have not been formed. It is thus not surprising that the post-blossom applications should be more effective, even though, with lime-sulphur solution, the dilution for post-blossom applications was considerably increased for such a sensitive variety as Cox's Orange Pippin.

Three applications (Expt. II.), one pre- and two post-blossom, of Bordeaux mixture and of lime-sulphur, yielded the best results, there being very little difference in efficiency between the two fungicides; Scab was reduced in both cases almost to zero. The importance of the application of the stronger lime-sulphur spray before blossoming is thus indirectly evident.

Both colloidal sulphur and very dilute lime-sulphur as post-blossom applications reduced infection (Expt. V.), though neither of them was consistently as effective as Bordeaux mixture or lime-sulphur (1—100) where a comparable number of applications was given.

2. *Method of Estimation of Scab on the Leaves.*

The amount of Scab on the leaves was estimated in 1928 and 1929 only, not in 1927. Each tree was inspected during the summer at definite periods, which were closely related to the times of application of the sprays. Thus, in order to ascertain the ultimate effect of any one application, the trees were inspected a few days prior to the succeeding one. A general survey of the plot was first made, to fix in the mind's eye the range of severity of infection and thus to secure a basis for the " category " method. After careful general observation of the leaves, each tree was given a category number. The numbers ranged from 0, free from Scab, to 5, severely scabbed. The figures in Table II. are averages of category numbers for groups of trees on the same rootstock submitted to the same spray treatment.

The following are the chief points arising from the results contained in Table II.

The value of a pre-blossom spray (as stressed in Salmon's work at Wye in 1908 (7) and by that of Brooks (2) in 1910) is again demonstrated. In both years its effect was visible until the season was well advanced, i.e., from the middle to the end of July, when the final survey on the leaves was made. Lime-sulphur was somewhat more efficient than Bordeaux mixture in 1928, as found by Frampton (3) in 1926; but in 1929, when hydrated lime was used, and rather severe scorching resulted,* there was little difference between them in their effect on Scab. It is noteworthy that when the new growth is effectively protected in its early stages of development, it remains relatively clean for a considerable period. The practical significance of this is important, as it shows that the result of neglect is cumulative, for, when early infections are allowed to develop, they tend to multiply until the tree becomes heavily infected.

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* Although severe damage was caused at East Malling, certain growers used Bordeaux mixture made with hydrated lime in excess on varieties other than Cox's Orange Pippin in the same season, and very slight injury resulted from the application. It is possible, therefore, that insufficient lime was used in these experiments.

TABLE II.

Control of Scab on the Leaves.

Variety—Cox's Orange Pippin.

Spray Treatment.		Stock	1928		1929	
			After 1st Post-	After 2nd Post-	After 1st Post-	After 2nd Post-
Experiment I.:						
B.M. + A.	1 pre-blossom ..	II.	1.6	2.0	1.2	2.0
L.-S. + A.	„		1.2	1.6	1.2	2.4
Control A.	„ ..		3.2	2.8	3.0	3.8
Experiment IV.:						
B.M. + A.	2 post-blossom ..	V.	1.0	1.0	1.0	0.4
L.-S. + A.	„ ..		1.8	2.0	1.6	1.0
Control A.	„		3.5	2.8	2.8	4.0
Experiment II.:						
B.M. + A.	1 pre- and 2 post-blossom	III.	0.0	0.2	0.0	0.0
L.-S. + A.	„		0.6	0.8	0.0	0.2
Control A.	„ ..		2.8	2.0	3.2	4.0
Experiment V.:						
L.-S. (1-150) + G.	2 post-blossom ..	X.	1.8	2.0	1.8	2.4
C.S. + G.	„ ..		1.2	1.6	2.0	2.2
Control G.	„ ..		2.2	1.7	2.8	4.0

The results indicate that heavy infections at the end of the season are due more to this cumulative effect than to additional infection from other trees. It follows that the effect of spraying is also cumulative, the pre-blossom application laying the foundation of protection which the weaker post-blossom applications are able to preserve more effectively than they could otherwise do.

With post-blossom applications only, both fungicides reduced infection considerably, Bordeaux mixture being superior to lime-sulphur. It will be noted that in 1929 there was less Scab on the trees thus treated as the season advanced. Existing Scab lesions were badly scorched by the fungicides, causing affected leaves to fall during the very hot weather which followed the application.

Three applications of either fungicide gave excellent results, Bordeaux mixture showing slight superiority in 1928. The value of the stronger pre-blossom lime-sulphur spray in counteracting the loss of effectiveness by the reduction in strength to 1-100 after blossoming is very evident from these results.

When applied as post-blossom sprays only, colloidal sulphur and very dilute lime-sulphur (1-150) had no lasting beneficial effect in 1928, but in 1929 both sprays reduced infection and were comparable in effect with a single, pre-blossom, application. As with the twigs, neither of these sprays was definitely superior to the other.

The seasonal effect on the incidence of Scab is very well shown by the figures in Table II. During 1928, there was (in each case) more Scab on the control trees after the date of the first post-blossom application to the sprayed trees than after that of the second. Lead arsenate has not been observed to scorch existing Scab lesions as the fungicides do, but leaves badly scabbed *early* in the season have been observed to fall prematurely during hot weather, as stated by Knoche (5).

Exactly the reverse occurred in 1929. That year was exceptionally dry and sunny; Scab did not really get the upper hand early in the season, but developed slowly, though surely, on the control trees. The results show a better control of Scab by the fungicides, while there was more Scab on the leaves as the season advanced. Heavy dews on many occasions in 1929 were most probably responsible for the steady development of Scab on unsprayed trees, in spite of the hot sunny days. An examination of the meteorological data at East Malling for June and July, 1929, support this explanation; for, on many occasions, the minimum night temperature was well below the dew point, while the trees were often laden with moisture early in the morning.

3. *Method of Estimation of Scab on the Fruit.*

The "category" method was again employed. A definite maximum area of Scab was fixed for each category, so that each maximum area was approximately double that in the category next below it. The choice of types was made by inspection after the range of severity of infection had been gauged as for Scab on the leaves. The four categories chosen are illustrated by Fig. I. In addition there was one category in which the fruits were Scab free; this was numbered 0. The first category was numbered ¼, and the others, in ascending order, were ½, 1 and 2.

The figures in Table III. were calculated by the same method as that used for Scab on the twigs, although the basis of comparison here was the *number* of fruits and not their weight.

In 1927 and 1928 the trees had not reached full bearing, consequently some of the figures cannot be regarded as significant, but they are generally supported by the figures from the much better crop in 1929.

The following points emerge from a consideration of the above figures.

There was no consistent evidence of Scab control by a single pre-blossom application of Bordeaux mixture or of lime-sulphur in 1927. This agrees with the results for that year on the twigs.

The beneficial effects of a single pre-blossom application are not so pronounced when Scab is checked early by dry weather conditions, such as occurred

Table III.

Control of Scab on the Fruit.

Variety—Cox's Orange Pippin.

Spray Treatment.		Stock	Average " Scab equivalent."		
			1927	1928	1929
Experiment I. :					
B.M. + A.	1 pre-blossom		34	25	6
L.-S. + A.	„		16	19	9
Control A.	„		27	71	37
B.M. + A.	„	II.	10	7	9
L.-S. + A.	„		23	11	15
Control A.	„		17	44	35
Experiment IV. :					
B.M. + A.	2 post-blossom	V.	2	13	3
L.-S. + A.	„		13	16	8
Control A.	„		30	57	24
Experiment II. :					
B.M. + A.	1 pre- and 2 post-blossom	III.	0	no fruit	0
L.S. + A.	„		3	10	1
Control A.	„		13	66	32
Experiment V. :					
L.-S. (1-150) + G.	2 post-blossom	VI.	insufficient fruit	57	12
C.S. + G.	„			45	17
Control G.	„			66	35

in 1927, but in 1928, though the number of fruits was not large, the amount of infection was reduced by the single application. Very good control was given in 1929 by both fungicides (see Fig. II., III. and IV.).

Efficient control was secured in all three years by two post-blossom applications of Bordeaux mixture and by dilute lime-sulphur, the former being slightly more effective.

Generally speaking, the control in both fungicides in all three years has been excellent when one pre- and two post-blossom applications have been made (see Fig. V. and VI.). Reference will be made in the section dealing with Spray Injury* to the fact that though Bordeaux mixture has proved to be such an efficient " scabicide " its use is not advisable on Cox's Orange Pippin owing to the serious damage it causes. Lime-sulphur, on the other hand, was only slightly less fungicidally effective at the strengths used ; and, during the course of these investigations, it has not been observed to cause any appreciable damage.

Colloidal sulphur and very dilute lime-sulphur (1-150) when applied twice, post-blossom, gave little control of Scab on the fruit in 1928, but in 1929 each reduced infection by about one half. There was no marked difference in effect between the two sprays. In 1927 there was insufficient fruit to afford any reliable figures.

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* See footnote, p. 230.

SPRAYS NOT CONTAINING LEAD ARSENATE.

Nothing has yet been said about the experiment, No. III., designed to show whether the inclusion of lead arsenate with the fungicides has any effect on their fungicidal value. Very few trees were used and the results obtained so far do not justify any definite conclusions being drawn. There are, however, indications that the addition of lead arsenate to lime-sulphur increases its fungicidal value, as stated by Grubb (4). The results are assembled below.

Influence of Lead Arsenate.
Variety—Cox's Orange Pippin.

Spray Treatment.	Stock	Scab on Leaves.	
		1928	1929
L.-S. + A. 1 pre- and 2 post-blossom ..	III.	0.8	0.6
Control A. ,, ..		2.0	3.7
L.-S. ,, ..	IV.	2.0	1.0
Control—No Treatment ..		2.5	3.5

Though the trials were made with trees on two different stocks, it will be seen that there was more infection on trees sprayed with lime-sulphur alone than on trees sprayed with lime-sulphur and lead arsenate.

In addition to the more extensive trials of Bordeaux mixture and lime-sulphur, described above, preliminary trials have been made with some of the newer and less well-known proprietary sprays for the control of Scab. Up to the present, no evidence has been obtained that any one of these sprays is superior to the Bordeaux or lime-sulphur, while some of them have caused considerable damage when used as recommended by the manufacturers. Reference will be made to this matter in the section on Spray Injury.

II. DUSTING EXPERIMENTS.

Dusting experiments are at present at a very preliminary stage. Certain cordon Cox's Orange Pippin trees on No. II. rootstock were placed at the author's disposal by Mr. H. B. Weston at East Malling. They were inspected just prior to blossoming, and some that appeared to be fairly uniform and gave promise of a fair crop were selected for experiment. They were all sprayed in the "pink bud" stage with lime-sulphur at 1-30.

Two post-blossom applications of dust were made, one at petal fall and the other three weeks later. Lime-sulphur 1-100 + gelatine (0.1%) was applied to certain other trees at the same times for comparison with the dusts. The dusts were applied with a hand blower and the lime-sulphur with a knapsack sprayer.

Three proprietary dusting sulphurs were used. The first dusting and spraying took place on June 4th, 1929, the weather being thundery. When the sun was not obscured it shone with rather a fierce heat.

The applications were made to adjacent trees in the row, those treated differently being well spaced by leaving a few cordons untreated between every two blocks of sprayed trees. The controls consisted of a distinct series of similar trees.

The second applications were made on June 24th, 1929. The weather was then warm and generally fine, though the sun was periodically obscured. There was very little Scab, its development probably having been checked by the "pink bud" spray and the subsequent drought.

The distribution of the spray and the dusts and their adhesion to the trees was very satisfactory. The dusts were applied rather more heavily than they probably would be in commercial practice, as the experiment was merely to obtain some preliminary data.

The main conclusion from the results obtained was that although the amount of Scab at the start, as already stated, was not great, yet the two post-blossom applications of spray and of dusts checked its further development. The dusts were not more effective than the spray; in fact, the latter was generally slightly the more effective of the two. The treatments caused no injury. It is clear that further trials with dusts are desirable.

III. THE INFLUENCE OF ROOTSTOCK.

Observations on the influence of the rootstock on the susceptibility of the scion to Scab were made concurrently with those on the effect of spraying. The figures in the following tables were obtained in the same way as described in detail in Section I. They refer, of course, to infection on the untreated control trees only.

(*a*) *Influence of Rootstock on Scab on the Twigs.*—This can be appreciated by a consideration of the results given in the following table.

It must clearly be understood that the figures in the above table cannot directly be compared column by column, i.e., one year with another, because, as shown in Section I, different methods were employed in obtaining them. Hence, though at first sight there appears to have been much more Scab in 1928 than in 1927 or in 1926, this is not necessarily so, because the figures are comparative merely as between stocks and not seasons.

TABLE V.

Influence of Rootstock on Incidence of Scab on the Twigs.
Variety—Cox's Orange Pippin.

Rootstock.	Scab in 1926.	Scab in 1927.	Scab in 1928	
I.	154	64	1000	Inducing susceptibility.
IX.	150	27	734	
XVI.	89	60	612	
IV.	64	35	556	Intermediate.
X.	130	14	456	
II.	191	23	322	
VI.	63	26	412	
V.	100	44	308	
III.	34	11	503	Inducing resistance.
XIII.	52	9	133	
XV.	9	0	47	

The stocks can tentatively be classified as follows :—

Stocks inducing susceptibility to Scab on Cox's Orange Pippin twigs—I., IX., XVI.

Stocks inducing moderate susceptibility to Scab on Cox's Orange Pippin twigs—IV., X., II., VI., V.

Stocks inducing resistance to Scab on Cox's Orange Pippin twigs—III., XIII., XV.

It will be seen from the table that these results are not absolutely consistent. The chief deviations are stock No. II., the trees on which were heavily infected in 1926 ; stock No. IX., the trees on which were only moderately infected in 1927 ; stock No. XVI, the trees on which were moderately infected in 1926, and stock No. III., the trees on which were moderately infected in 1928.

Statistical analysis of the figures has established the significant existence of the three groups, although some of the smaller differences between the individual stocks may be due to chance, and therefore not significant.

The extremes of susceptibility are Cox on No. I., heavy infection, and Cox on No. XV., slight infection. Seasonal variation probably largely accounts for the individual divergence between these results and those obtained in 1925 by Frampton, when trees on No. I stock were relatively resistant and those on No. IV. and V. were very susceptible.

In making comparisons between different rootstocks, based on infection on the lead arsenate-sprayed controls, it has been assumed that this spray has no fungicidal effect against Scab. The figures, supplemented by general observation, support this assumption.

(*b*) *Influence of Rootstock on Scab on the Leaves*—This is indicated in the results shown in the following table.

TABLE VI.

Influence of Rootstock on Incidence of Scab on the Leaves.

Variety—Cox's Orange Pippin.

Rootstock.	Estimation after 1st post-blossom application.		
	Scab in 1928.	Scab in 1929.	
IX.	3.2	3.5	Relatively susceptible.
I.	3.5	3.0	
V.	3.5	2.8	
II.	3.2	3.0	
III.	2.8	3.2	Intermediate.
VI.	2.3	3.0	
X.	2.2	2.8	
XVI.	2.3	2.7	
XIII.	1.8	2.5	Relatively resistant.
IV.	2.0	2.0	
XV.	1.5	2.0	

Two years' data only have been obtained of the amount of Scab on the leaves, but these also indicate an influence of rootstock on the susceptibility of Cox's Orange Pippin to Scab. The figures do not conform in detail to the classification based on twig infection, but in general there is a distinct similarity. Stocks No. I. and No. IX. again appear in the relatively susceptible group, while stocks No. XIII. and No. XV. again form the other extreme. Trees on the other stocks fall between these extremes in no very well-defined order. Noteworthy cases of variation are trees on No. IV. stock (twigs moderately susceptible, leaves relatively resistant) ; on No. V. stock (twigs moderately susceptible, leaves relatively very susceptible) and on No. XVI. stock (twigs relatively very susceptible, leaves moderately susceptible).

It follows that although a tree may bear heavily infected leaves, the shoots need not necessarily be also heavily infected. Thus, the degree of susceptibility due to the rootstock cannot be indicated in every case solely by the amount of infection on the shoots or by that on the leaves, although in many cases, the expression of one also represents the other.

(*c*) *Influence of Rootstock on Scab on the Fruit.*—Up to the present the trees have yielded insufficient fruit to provide complete information. Those on certain stocks have cropped fairly well, but the results are too inconsistent to be reliable, owing to the small number of fruits available. Trees on stocks No. I., IX. and XIII. have, however, yielded sufficient data to show that the fruit on trees on stock No. XIII. was much more lightly infected than that on trees on the other two stocks, thus supporting the results obtained with twigs and leaves.

Further results on the effect of rootstock on the susceptibility of the fruit will be found in Table VII., in which the data for one year (1929) with Bramley's Seedling and Worcester Pearmain are presented.

It will be seen that with Worcester Pearmain, stock No. IV. has induced heavy infection, and so, to a less extent, have stocks No. VI. and VII., while trees on No. V. are lightly infected by comparison. This holds good both for the manured and for the unmanured plots.

With Bramley's Seedling it will be seen that on the manured plot, trees on stocks No. I., II. and IV. were heavily infected in comparison with those on stocks No. V. and III. This order does not hold good on the unmanured plot, where trees on No. I were, in comparison, most lightly infected, although the actual amount of infection was greater than that on comparable trees on the manured plot. These results indicate a differential response of No. I rootstock to manuring. Trees on stock No. V on the unmanured plot were comparatively lightly infected, as were those on the manured plot, thus indicating no differential response. At the other end of the scale are trees on stocks No. X. and No. VII. which, on the unmanured plot, were relatively most heavily infected.

Statistical analysis of the figures shows that though the extremes differ significantly, the smaller differences, although they appear significant, are not really so.

The results given above indicate the necessity for ensuring that experimental data are obtained only from uniform material.

IV. THE EFFECT OF MANURING.

The influence of manuring on the incidence of Apple Scab has been, up to the present, but little explored. Beach (1) found that the application of wood ashes did not prevent Scab in 1897. Munson (6) states that an excess of potash did not ward off Scab. At East Malling, Grubb has recently found more Scab on an apple plot treated with potash than on a comparable potash-" starved " plot.

The results now presented were obtained in 1929 with fruit of Worcester Pearmain and Bramley's Seedling.

Two plots of these varieties, worked on various rootstocks, have been used since 1920 to test the effect of manuring on general " tree performance," i.e. on vigour and fruitfulness. The trees in the two plots are similar in regard to variety, age, rootstock and general treatment. One plot, the " starved " one, has had no manure since 1920, although, to keep the soil in good condition, green crops of mustard, cabbage, or rape have been grown on it and ploughed in. The manured plot has received annual dressings of balanced manures. These were as follows :—

1919/20. Shoddy, lime and soot.
1920/21. Dung.
1921/22. Shoddy and fish meal.
1922/23. Dung and bone siftings.
1923/24. Shoddy, meat and bone meal.
1924/25. Dung. Muriate of potash and rape dust.
1925/26. Shoddy, meat and bone meal and Peruvian guano.
1926/27. Sulphate of potash. Meat and bone meal.
1927/28. ,, ,,
1928/29. ,,

There was a large crop of fruit on both varieties in 1929, and this was graded for Scab by the " category " method already described. Random samples of fruit from each tree were graded as the time available was not sufficient to deal with the full crop. An occasional check was kept by taking more than one random sample from a tree, grading the fruit in each sample separately, and comparing the results. By this means the method and the results proved to be very satisfactory. The results are given in Table VII., the figures being the relative " Scab equivalents."

TABLE VII.

Effect of Manuring on the Incidence of Scab on the Fruit. 1929 *Crop.*

Worcester Pearmain.				Bramley's Seedling.			
Stock	Manured.	Stock	Un-manured.	Stock	Manured.	Stock	Un-manured.
IV.	79	IV.	173	I.	70	X.	327
VII.	74	III.	139	II.	67	VII.	322
VI.	64	VII.	131	IV.	65	VI.	256
I.	62	VI.	125	VII.	62	II.	239
III.	61	II.	90	X.	56	III.	230
II.	59	X.	84	VI.	55	IV.	181
X.	50	I.	75	V.	52	V.	177
V.	48	V.	65	III.	48	I.	175

It should be stated that the trees on *both* plots were sprayed twice with lime-sulphur, firstly in the "pink bud" stage, at a strength of 1-30, and secondly soon after petal fall, at a strength of 1-100.

Statistical analysis of the figures shows that in spite of spray treatment the fruits of both varieties on the starved plot were significantly very much more heavily scabbed than those on the manured plot, although Bramley's Seedling shows the difference more strikingly than Worcester Pearmain does. A similar effect was also indicated in certain data collected by the pomology staff in 1928 on the Worcester Pearmain fruit from the two plots, the data being based on the *numbers* of scabbed and clean fruits.

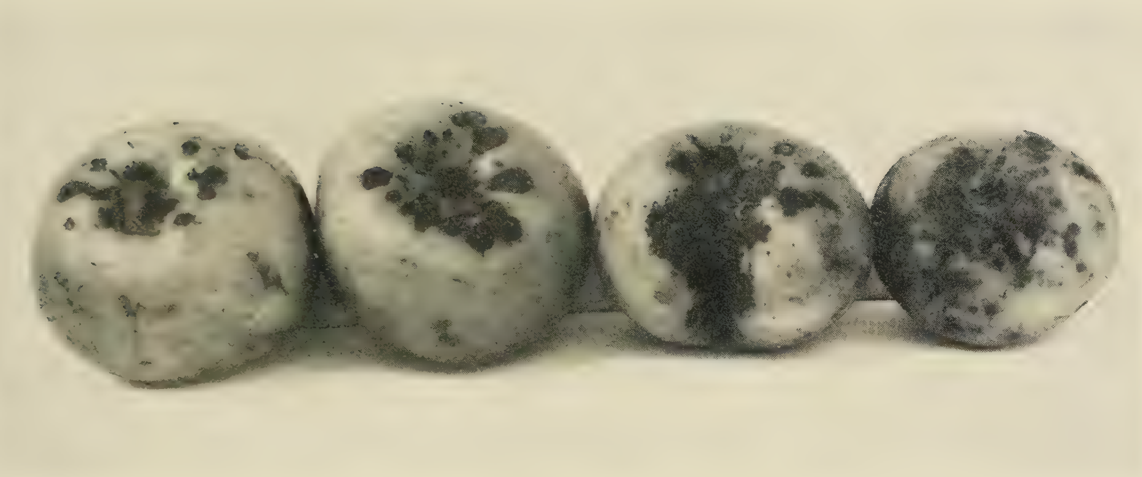
Figures VII. and VIII. show the fruit taken at random from two Bramley's Seedling trees, one on the manured, the other on the "starved" plot, and the "Scab equivalent" in the table may be compared with the amount of Scab visible in the reproduced photograph. The heavily infected fruit has a "Scab equivalent" of 384 while that of the lightly infected is only 32. In this particular case there was more than ten times as much Scab on the unmanured as on the manured plot, and it must be admitted that this particular example represents rather an extreme case, for the trees were selected at random. It illustrates the large individual differences that occurred, although the average normally shows only from three to five times as much Scab on the "starved" Bramley fruits as on the manured. This average difference is a very large one, and represents the effect of the manure in checking Scab in the one particular year. It also indicates a probable reason why a spraying scheme may prove of great value in some cases and of no avail in others.

These results do not show whether the manurial effect is due to any specific component, but they do indicate that complete manurial dressings played an important part in relation to Scab infection *in 1929*. This result is of practical importance, although in the light of existing knowledge, it is not suggested that suitable manuring will render spraying unnecessary. From the experimental standpoint it is evident that the manurial factor may be one cause of variable results just as the rootstock factor has been shown to be.

V. Summary and Conclusions in Regard to Apple Scab.

1. A full description is given of certain spraying experiments on the control of Scab, together with the methods used for obtaining comparable results.

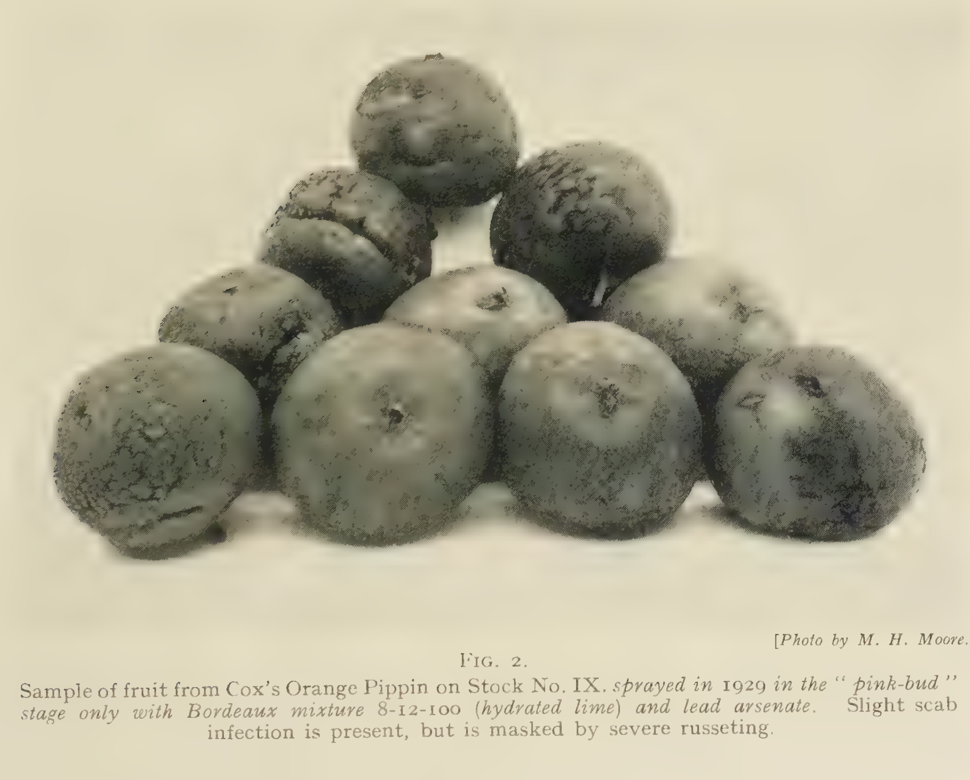
2. The results obtained are :—The disease was checked on the twigs, leaves and fruits of Cox's Orange Pippin by Bordeaux mixture and by lime-sulphur, both containing lead arsenate, when applied, (a) once, before blossoming, when there was little difference in effect between the two fungicides, (b) twice, after blossoming, when Bordeaux proved superior (lime-sulphur having been reduced in strength), (c) once before, and twice after blossoming, when excellent control was given by both fungicides. The results suggest that the efficiency of lime-sulphur against Scab on the leaves is increased slightly by the addition of lead arsenate. Bordeaux mixture proved on the whole to be more effective, although owing to the severe injury caused, its use on this variety is not advisable. Salmon (8), in 1911, came to the same conclusion. This point will be dealt with more fully in the section dealing with Spray Injury. Colloidal sulphur and very weak lime-sulphur, as post-blossom applications only, gave some control ; neither was consistently better than the other, and neither was as efficient as Bordeaux mixture or the stronger lime-sulphur.



[*Photo by M. H. Moore.*

FIG. 1.

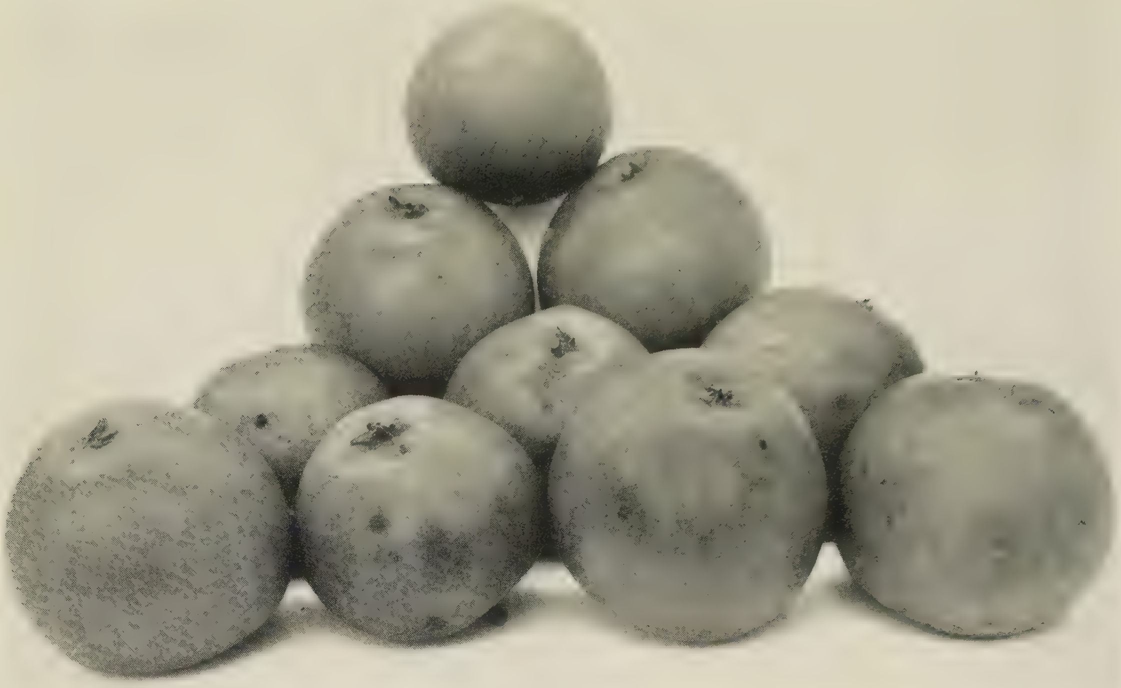
Four type Apples, showing maximum Scab grades used in "category" method of grading the fruit ($\frac{1}{4}$, $\frac{1}{2}$, 1, 2. See p. 238).



[*Photo by M. H. Moore.*

FIG. 2.

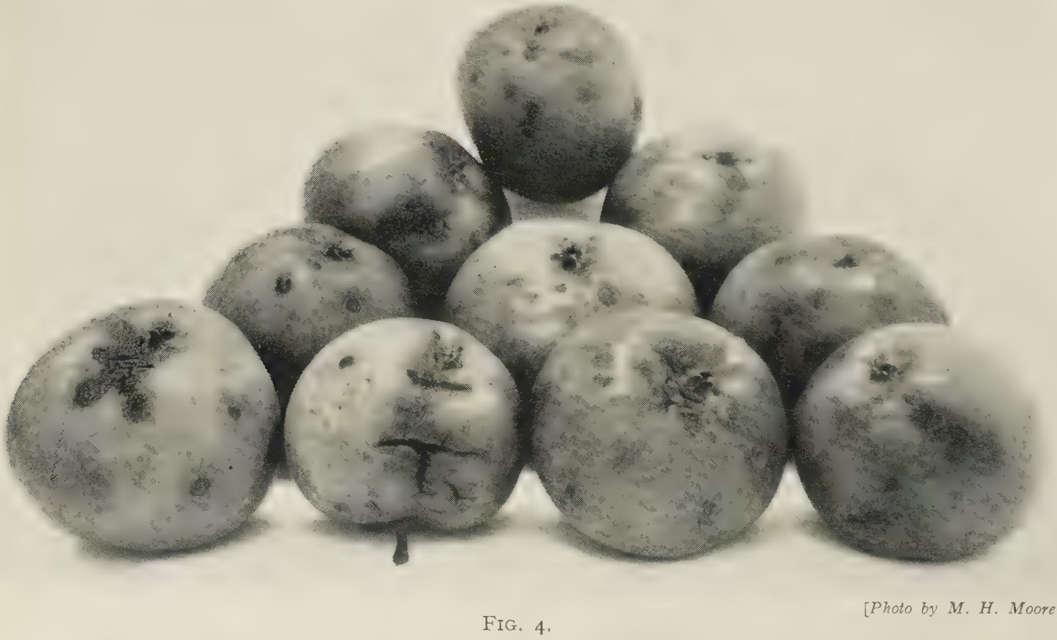
Sample of fruit from Cox's Orange Pippin on Stock No. IX. *sprayed in* 1929 *in the "pink-bud" stage only with Bordeaux mixture* 8-12-100 (*hydrated lime*) *and lead arsenate.* Slight scab infection is present, but is masked by severe russeting.



[*Photo by M. H. Moore.*

FIG. 3.

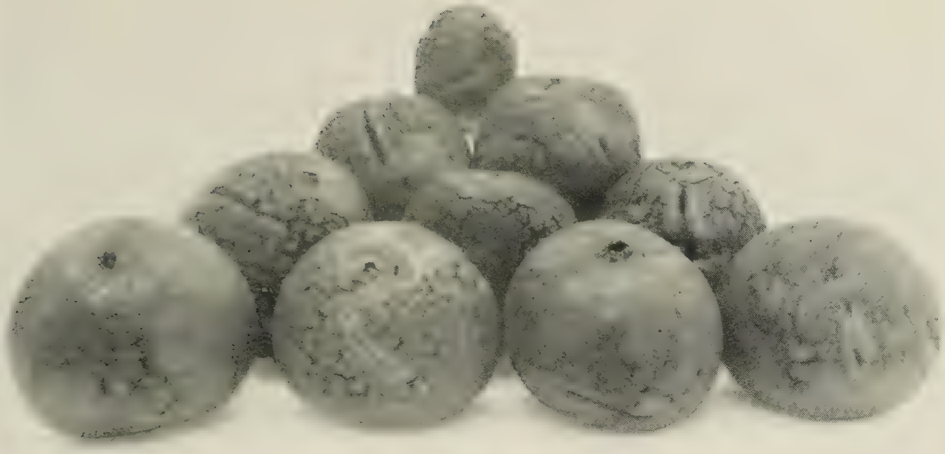
Comparable with Fig. 2, but *sprayed with lime-sulphur and lead arsenate.*
Scab infection very slight.



[*Photo by M. H. Moore.*

FIG. 4.

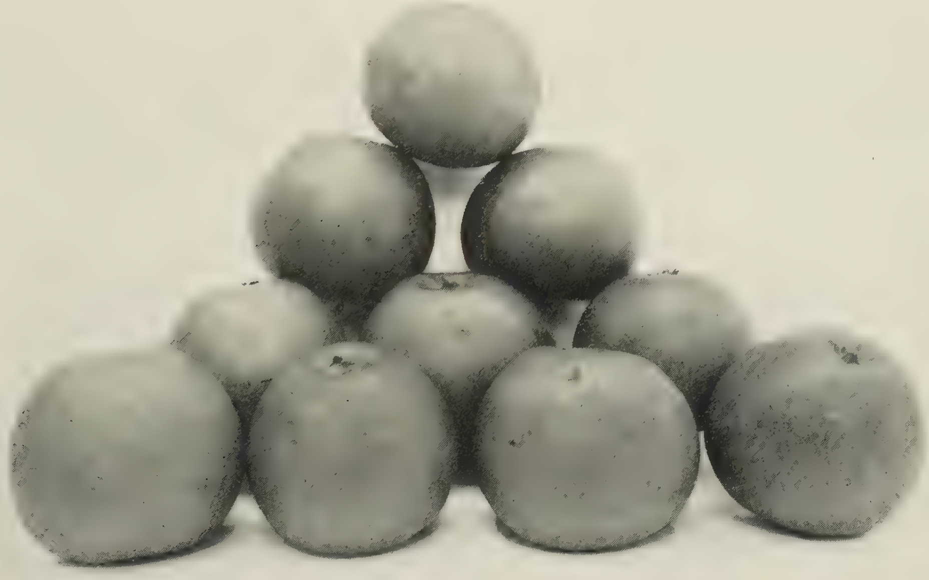
Comparable with Fig. 2 and 3, *but sprayed with lead arsenate in water* as control.
Note heavy Scab infection.



[Photo by M. H. Moore.

FIG. 5.

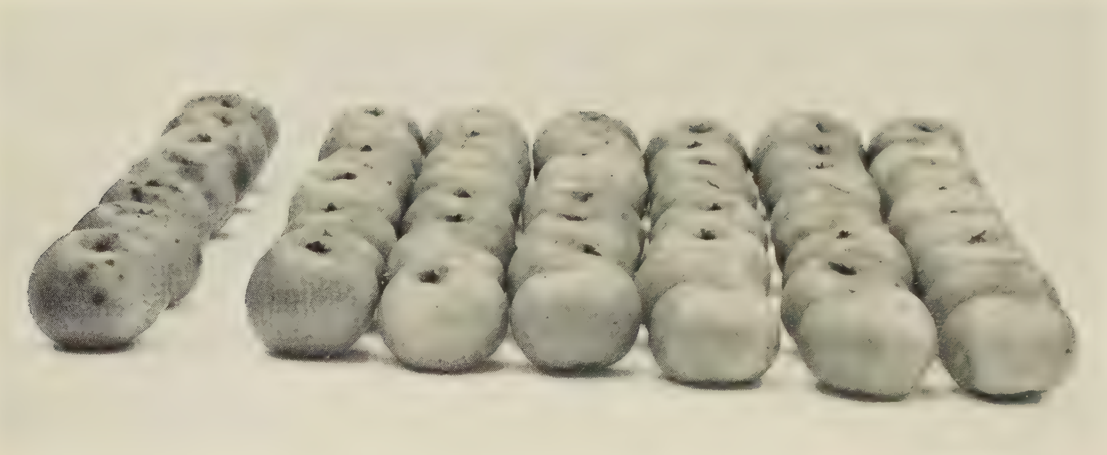
Sample of fruit from Cox's Orange Pippin on No. III. Stock, *sprayed once before and twice after blossoming with Bordeaux mixture and lead arsenate.* Excellent control of Scab, but very severe russeting.



[Photo by M. H. Moore.

FIG. 6.

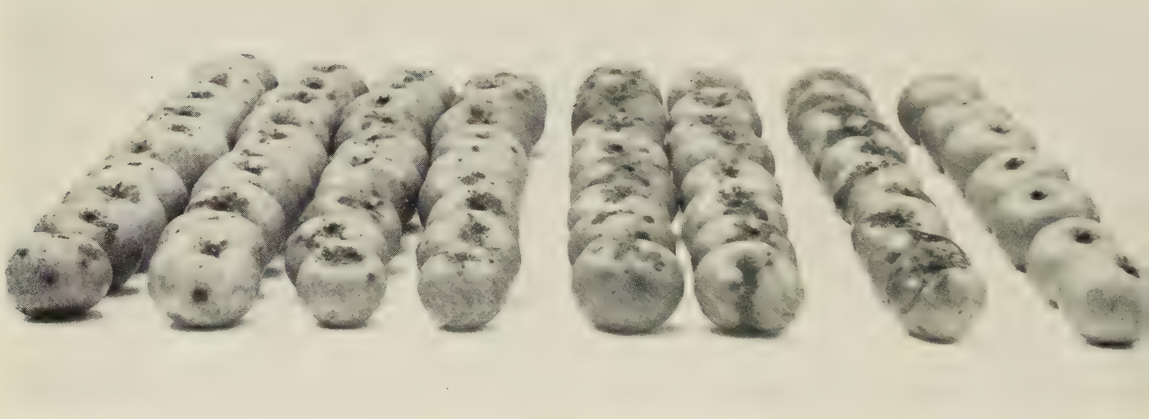
Comparable with Fig. 5, but *sprayed with lime-sulphur and lead arsenate.* Excellent control of Scab and no russeting or other blemish.



[Photo by M. H. Moore.

FIG. 7.

Sample of Bramley's Seedling fruits from tree on No. VII. Stock on *manured* plot. Sprayed pre- and post- blossom with lime-sulphur. Few scabbed fruits.



[Photo by M. H. Moore

FIG. 8.

Comparable sample of Bramley's Seedling fruits from tree on No. VII. Stock on *unmanured* plot. Same spray treatment as fruits shown in Fig. 7. Heavy Scab infection.

3. The scab " pustule " or lesion on the young wood of Cox's Orange Pippin is described as consisting of a series of " pads " of mycelium separated by corky tissue. The bark covering the pads splits in due course and the spores are liberated in succession over a considerable period.

4. A preliminary trial of sulphur dusts as compared with a lime-sulphur spray is described, and the results for one year indicated. Generally speaking, the dusts proved slightly inferior to the spray, although the differences in the figures were small. There was no consistent evidence of injury following these treatments.

5. It is shown that both rootstock and manurial treatment have a marked influence on the degree of infection by Scab. There is evidence that different scion varieties react differently in this respect according to the rootstocks on which they are " worked," while a possible differential effect of manuring on the influence of the rootstock is indicated.

The effect of manuring on Scab incidence on the fruit has been determined for one year only, and the results are supported, in general, by records taken in 1928 of the percentages of clean and scabbed Worcester Pearmain apples from the manured and unmanured plots.

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THE EFFECT OF SCION ON ROOT.*

II. STEM-WORKED APPLES.

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In the Annual Report of the East Malling Research Station for the year January to December, 1923, some preliminary observations were published concerning the effect of scion on root (1).

Since the number of plants examined was comparatively small, it was indicated that the work would have to be repeated on a much larger scale.

The tentative conclusions then drawn were that, whatever scions were budded upon rootstocks of such widely contrasted characteristics as the very fibrous Rivers' Nonsuch Paradise (Malling No. VI.), and the coarse fangy rooted Doucin (Malling No. II.), the characteristics of these rootstocks remained absolutely distinct, and approximating to type. Certain quantitative differences were apparent with regard to the actual weight of roots in proportion to the weight of the whole tree. For instance, where No. II. was used, the weight of roots was 19 per cent. of the whole tree for Newton Wonder, and 31 per cent. for Grenadier, and where No. VI. was used the root weight of Newton was 13 per cent. as against 26 per cent. for Grenadier. Yet both varieties worked on No. II. had only from 13 to 15 per cent. fibre, whereas on No. VI. they had from 37 to 39 per cent.‡

Thus, in spite of the fact that on both stocks the root system of Grenadier formed a much greater proportion of the whole tree than that of Newton Wonder, the root systems retained their typical characteristics.

It also appeared that although the percentage of fibre on Doucin No. II. rootstock might vary from 13 to 18 per cent. according to the variety of scion, and on Nonsuch No. VI., from 37 to 39 per cent., yet it was obvious that the most fibrous series on No. II. bore less than half the amount of the least fibrous series on No. VI.

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* For Part I of this Series see literature cited (1).

† Acknowledgment is due to the propagation and recording staff of the Station for the careful detailed work involved in preparing the trees and obtaining the data which are here discussed.

‡ In this experiment all roots with a diameter of less than 3mm. were classed as fibre.

How far these variations in total root weight and percentage of fibre, within any collection of scion varieties on one particular rootstock, are attributable to a qualitative or merely quantitative influence of the scion is discussed subsequently in this paper.

As a result of these preliminary indications, a much more extensive series of trees, including a wider range of both rootstocks and scions, was prepared. As indicated in the Annual Report for the year 1927 (2), these trees were lifted during the winter 1927-28, the series at that date including both one and two year old trees. In addition to the worked (i.e., budded) material, unworked stocks similarly treated (i.e., cut back to a single bud) were included in this experiment. It is the numerical data resulting from the analyses of these trees which will be reviewed in the present paper. Before so doing, however, it should be made perfectly clear that all the trees referred to in this and the earlier report were budded on to the *stems* of layered rootstocks, this being practically the universal custom in Europe, and by which method it has now been abundantly proved possible to utilise to the full extent the influences of which the different rootstocks are capable.

A visit to the Eastern States of America in 1923, showed that for apples this method of working trees was little used in comparison with that of bench grafting directly upon whole or piece roots of seedlings ; and at the same time it became quite clear that American nurserymen claimed that they could identify their apple varieties after they were dug up, merely by the characteristics which the scions imparted to the roots. Not a few research workers appeared to accept this claim but the recent and preliminary work of Swarbrick and Roberts (3) affords the first attempt to obtain scientific information on the subject. This aspect of the subject, which raises a most interesting theoretical point as to where rootstock influence originates, has not been neglected in its relationship to layered stocks. As far back as 1924 a series of trees were bench grafted for this purpose. Unfortunately scion rooting under such conditions proved so frequent, that the original piece roots became quite subordinate and so were useless for analysis (2). However, it has now been possible to examine a further batch of trees grafted on piece roots of layered stocks together with controls which were stem grafted, and some trees on seedling stocks, to supplement the work done on stem worked trees at East Malling and to see whether clonal piece roots behave similarly to the seedling roots used by the above mentioned writers. The results of this examination are being presented simultaneously with this paper, as Part III of the series.

MATERIAL USED.

In the winters of 1924-25 and 1925-26 series of one year rootstocks, carefully graded for size, were planted out straight from the stool bed, at the ordinary nursery distances, an effort being made to plant the stocks as nearly as possible at the same depth. In the succeeding summers these rootstocks were budded, with the exception of a certain number of two varieties of rootstock, specially selected for the widely differing nature of their root systems, i.e., Nos. II and VI. When the worked stocks were " snagged," i.e., cut down just above the place where the bud had been inserted, those which were left unworked were cut down to a similar height above ground level, so as to produce fresh growth comparable with the " maiden " growth of the worked trees. The varieties of rootstock chosen were Malling Nos. I and VI, II, and IX.*

To the six scion varieties used in the earlier experiment already referred to, i.e., Bramley Seedling, Stirling Castle, Grenadier, Newton Wonder, Lord Derby and Beauty of Bath, Cox's Orange Pippin was added.

The trees raised in the earlier year were allowed to " feather " in the second year and both these and the succeeding " maiden " series were carefully lifted, as far as possible with all roots intact, during the winter of 1927-28.

METHOD OF ANALYSIS.

The method of lifting was to dig a trench beyond and below the range of roots and work gradually forward until the trees were free. The roots were then washed and transferred to the laboratory for examination. In all, some sixteen separate weighings and measurements of the stem and roots of each individual tree were recorded, those which are to be here discussed being the total weight of tree, weight of root system, weight of fibre and coarse roots. These divisions must necessarily be to some extent arbitrary, but for this purpose all roots of less than 2 mm. diameter were described as fibre and those above this as coarse roots.

The number of fine rootlets developed by a root system has been regarded as some indication of the total absorbing capacity of the system. The absorbing function, however, is carried out only near the tips of young rootlets and it is manifestly impracticable in excavating large numbers of extensive root systems to recover from the soil the whole, or even the greater part, of these growing tips. Therefore it has been the practice to consider the total weight of the finer roots recovered as being an approximate indication (the best at present obtainable in large scale experiments) of the absorbing capacity of the whole system. These finer roots have been generally designated " fibre " in contrast to the " coarse roots " which form the main scaffolding of the root system. Their origin, function and eventual fate need not be discussed here, but it has been repeatedly observed that whilst each variety of layered rootstock possesses a definite and constant degree of " fibrousness " there are marked visible differences in this character when different varieties of rootstock are compared, and in fact the nurseryman and grower regard the amount of "fibre" as some measure of the potentialities of a root system. In characterising root systems quantitatively, therefore, the degree of fibrous development has been measured by expressing the weight of fibre as a percentage of the total weight of roots (1).

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*I. Broad leaved English Paradise; VI. Rivers' Nonsuch; II. Doucin; IX. Jaune do Metz.

Table I. gives results for four varieties worked on Doucin (No. II.) and Nonsuch (No. VI.) showing figures of the total weight of the root systems and of the proportion of that total weight represented by fibre.

TABLE I.

Analysis of Roots of Maiden Trees on two Rootstocks.

	No. VI.					No. II.				
Variety of Scion.	No. of Trees.	Total Weight of Roots.		% Fibre.		No. of Trees.	Total Weight of Roots.		% Fibre.	
		Mean.	S.E.	Mean.	S.E.		Mean.	S.E.	Mean.	S.E.
Unworked ..	14	*29.1*	2.3	*50.3*	4.6	15	*45.9*	3.3	*25.0*	1.5
Lord Derby ..	15	*30.8*	2.9	*53.1*	2.8	15	*36.4*	2.4	*31.1*	2.1
Beauty of Bath ..	10	*28.6*	2.6	*52.0*	3.7	12	*43.0*	3.1	*27.9*	1.7
Grenadier	14	*29.7*	2.9	*41.9*	2.9	12	*51.0*	5.9	*26.7*	2.5
Newton Wonder	14	*33.2*	2.6	*47.1*	3.0	16	*45.9*	3.4	*23.2*	2.1

In the first place these figures leave no doubt that there is a measurable difference in total weight of root between Nos. II. and VI. unworked. When the root growth of the same two stocks worked with four varieties is examined it will be seen that in every case the general family likeness of the root system persists, the differences in total root weight as between No. II. and No. VI. being highly significant with the exception of that shown by Lord Derby. When different varieties on the same rootstocks were compared, it is found that there is no significant difference between any two varieties on any one stock. In other words, in respect of total root weight each rootstock has maintained its individuality irrespective of the scion worked upon it, and the difference between two stocks has remained unimpaired when each is worked with the same scion.

This statement holds, of course, only for the maiden trees under examination and it is realized that significant differences in total root weight may result from the use of other varieties as scions and in older trees (see for instance Table IV.)

The figures for percentage of fibre also show a similar family likeness when the rootstock is of the same variety, whilst striking differences appear, even with the same scion, when two stocks are compared. In the case of the unworked stocks the difference in percentage fibre is nearly five times its standard error and its significance cannot be questioned.

Comparing the averages for the unworked trees on VI. and the varieties worked thereon, only two significant differences appear. Thus, the trees of Grenadier have a smaller percentage fibre than those of Lord Derby, and probably also than Beauty of Bath, although none of these varieties differs significantly in total root weight.

If the corresponding series on Doucin (No. II.) is examined, Lord Derby, which in this case has the least heavy root system, again has the highest percentage of fibre, though here the difference between Derby and Grenadier is not so apparent.

That Lord Derby should possess this characteristic in each of these two groups is at least suggestive of scion influence upon root character in view of the results of the earlier trial.

The series of two year old trees was next examined to see whether these differences were maintained after a further year's growth. Table II. summarizes these results, and typical trees are shown in Figures 1 and 2.

TABLE II.

Analysis of Roots of Two Year old Trees on Rootstocks.

Variety of Scion.	VI.					II.				
	No. of Trees.	Total Weight of Roots.		% Fibre.		No. of Trees.	Total Weight of Roots.		% Fibre.	
		Mean.	S.E.	Mean.	S.E.		Mean.	S.E.	Mean.	S.E.
Unworked	10	*41.7*	3.1	*51.3*	4.3	12	*60.2*	4.6	*18.8*	1.9
Lord Derby ..	12	*41.8*	3.2	*53.7*	5.3	14	*53.1*	3.4	*28.1*	2.1
Beauty of Bath ..	10	*47.1*	4.6	*42.9*	2.5	12	*54.2*	4.2	*24.3*	1.3
Grenadier	13	*62.7*	5.2	*37.6*	1.5	11	*61.8*	6.5	*22.4*	3.1
Newton Wonder ..	10	*41.7*	5.1	*67.5*	4.7	10	*54.4*	6.0	*24.4*	2.3

In the two year old series of trees, the unworked stocks differ in mean percentage fibre by more than seven times the stand error of the difference. When once more these varieties are compared on the two stocks, the differences are no less significant. When, however, the possible influence of the different scions at two years old is sought for, it will be seen that this time from the series on No. VI., Newton has significantly more fibre than all the other varieties, and Grenadier a smaller percentage than all but Beauty of Bath ; and although in the series on No. II. Lord Derby has significantly more fibre than the unworked

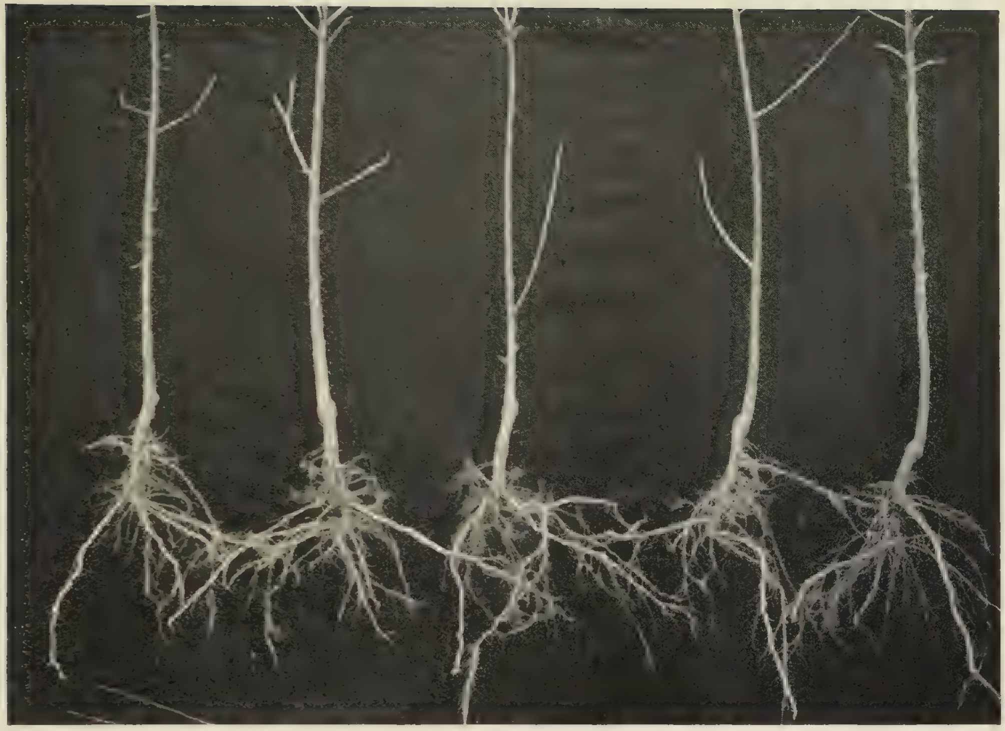

FIG. 1.

Two year olds—left to right. Doucin No. II. unworked; Newton Wonder, Grenadier, Beauty of Bath and Lord Derby all budded on No. II.

Note general similarity of root character and contrast with Figure 2.

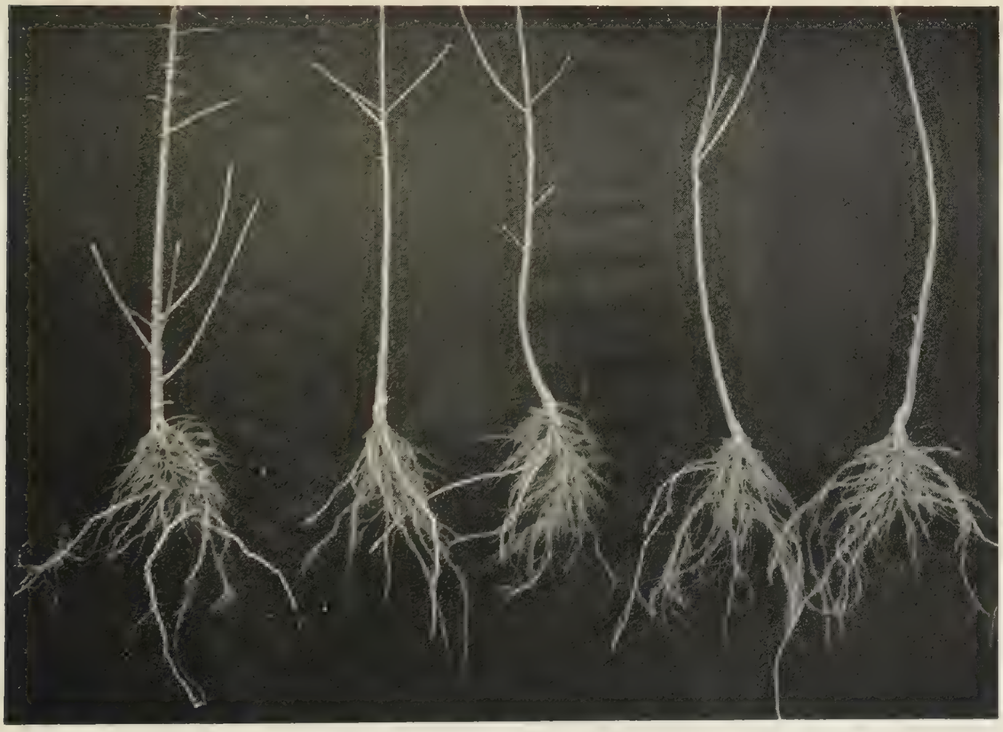

FIG. 2.

Two year olds—left to right. Nonsuch No. VI. unworked; Newton Wonder, Grenadier, Beauty of Bath and Lord Derby all budded on No. VI.

trees, it is not possible to prove it more fibrous than its companion varieties in this case.

The performance of Newton and Grenadier in combination with these stocks in this case is of great interest when considered in relation to a fact which was shown first in the earlier experiment (I., p. 112) and strikingly confirmed in this trial. As Table III. shows, in every case Newton Wonder has made the heaviest stem in relation to the root development, whereas Grenadier has invariably made the smallest stem growth in proportion to its roots.

Table III.

Stem Weight as a percentage of the Weight of the Whole Tree.

	One year old trees.				Two year old trees.			
	On VI.		On II.		On VI.		On II.	
	Total Weight of Tree.	% of Stem.	Total Weight of Tree.	% of Stem.	Total Weight of Tree.	% of Stem.	Total Weight of Tree.	% of Stem.
Unworked ..	176	83.5	209	76.1	246	79.3	322	81.4
Derby ..	176	82.4	194	81.4	243	77.8	265	80.0
Beauty of Bath	156	81.4	219	80.4	240	82.1	315	82.9
Grenadier ..	137	78.1	211	75.8	254	75.2	231	73.2
Newton ..	207	84.1	278	83.1	70	84.5	334	83.8

Should further confirmation be required of the main fact that, even if scion variety may alter to some small extent the characteristics of a root system, different rootstocks themselves remain distinct, another series of Bramley Seedling and Cox's Orange Pippin on Malling Nos. I. II. and IX. amply confirm the comparative lack of fibre on No. II. (See Table IV.)

Thus the root systems of No. I under Cox's and Bramley have respectively 34.6 per cent. and 36.1 per cent. fibre and the corresponding root systems of No. II. have 19.7 per cent. and 16.8 per cent., the differences in both cases being beyond question.

Before proceeding further, some consideration is necessary of how far the figures of "percentage fibre" may be used to characterize a root system.

It appears that, although highly significant differences in percentage fibre have been recorded for the trees on different stocks, a portion of these differences may be attributed to factors other than the inherent characters of the different root systems, and similarly the differences in percentage fibre resulting from the use of different varieties as scions are probably not wholly an expression of an alteration in the character of the roots.

TABLE IV.

The Total Weight of the Root System and the percentage fibre of Two year old trees of Cox's Orange Pippin and Bramley Seedling on Nos. I, II and IX.

On Nos:—	I.					II.					IX.				
	No. of Trees.	Total root weight	S.E.	% Fibre.	S.E.	No. of Trees.	Total root weight	S.E.	% Fibre.	S.E.	No. of Trees	Total root weight	S.E.	% Fibre.	S.E.
Cox	20	62.3	3.9	34.6	2.9	24	94.8	4.6	19.7	1.0	18	34.8	2.1	30.4	2.1
Bramley	24	60.3	3.0	36.1	2.1	22	104.9	4.5	16.8	0.8	19	58.3	3.1	24.5	1.8

INTERPRETATION OF FIGURES OF "PERCENTAGE FIBRE."

Although it appears at first sight that such values may be used as an adequate representation of differences in "fibrousness" which are visible on inspection of different root systems, further examination make it abundantly clear that the figures must be used with extreme care.

Consider, for example, a young tree which has been denuded of all its roots and replanted. Within a few weeks some new roots will develop adventitiously from the stem and these in the early stages will have a diameter of perhaps 2 or 3 millimeters. If all roots having a diameter of, say, 3 mm. or less are to be classified as "fibre," it is evident that at this early stage 100 per cent. of the root system will be fibre. As the tree grows, however, some of the roots will increase in diameter and length and will pass from the "fibre" grade into the "coarse root" grade, the younger portions of the root system taking their place as "fibre." The result of this process is a decrease in the percentage of fibre in the system as a whole, and this decrease will continue as the root system increases in size. It is at present impossible to state how long this gradual decrease in the percentage of fibre may continue, but it is obvious that, with an increase in total weight of roots, the percentage of fibre may be expected to decrease, and the ratio of weight of fibre to total weight of root is not a constant character of any variety of root system. It is quite evident on inspection, however, that root systems of different varieties show widely different proportions of fibre, though these differences cannot be accurately expressed as simple percentages without taking into account the relative sizes of whole root systems.

A large series of trees is being prepared for an investigation of the matter and in the meantime an example may be quoted from a batch of seventy-six trees of Broadleaf (No. I.) apple stock (unworked) three years old. The total weight of root system varied from 40 gms. to 120 gms. and the percentage of fibre varied from 41 to 10. It is hardly to be expected that the whole seventy-six trees should fall into a perfectly graded series, ascending total weight being accompanied by descending percentage of fibre, but if these seventy-six trees be grouped according to total weight of roots the general trend of the percentage of fibre is amply demonstrated. (Table V.)

Doubtless with a larger number of trees it would be possible to narrow the limits of each group and still show such a gradation, in spite of the inevitable variation in material and of unavoidable errors of excavation and recording.

If, then, it is desired to use the ratio of fibre to total roots in order to express visible differences in the nature of two different root systems, it is necessary to take into account the relative size of the two systems, which the sequel will show to be not always a simple matter. It is, however, often possible to apply a method of grouping similar to that used in Table V., provided a large

TABLE V.

Percentage of Fibre in Relation to Total Weight of Roots. Apple Stock No. I. unworked.

No. of Trees.	Total Weight of Roots.	Percentage of Fibre.
19	41–60 gms.	24·8
35	61–80 gms.	20·7
17	81–100 gms.	19·1
5	101–120 gms.	15·6

enough unit of trees is available. This has been done in Table VI. with a number of trees of Bramley's Seedling and Stirling Castle, two years old, worked upon Stock No. I., and some unworked stocks of No. I. of the same age.

Within each combination of stock and scion it is evident that the proportion of fibre decreases with increasing size of root system, but when trees with different scions are considered, the proportion of fibre is approximately the same within groups with root systems of similar size, even though only small numbers of trees were available.

In such a case as this there appears to be good evidence that the proportion of fibre is a characteristic feature of the root system and is not changed by the influence of different scions, although if averages are worked out for each batch of trees with the same scion irrespective of total size of roots, marked differences may be obtained.

It should be emphasized that in order to render such comparisons valid, the number of trees used must be large, so that each size group may contain a

TABLE VI.

Percentage of Fibre in Relation to Total Weight of Roots. Bramley's Seedling and Stirling Castle on No. I. and also No. I. unworked.

Total Weight of Roots.	Bramley on I.		Stirling on I.		I Unworked.	
	No. of Trees.	% Fibre.	No. of Trees.	% Fibre.	No. of Trees.	% Fibre.
21–35 gms. ..	8	46·3	19	44·1	5	41·0
36–50 gms. ..	12	33·5	11	34·7	7	36·1
51–65 gms. ..	10	27·5	5	27·4	6	28·5

reasonable number of individuals, and also to ensure that comparable size groups may be obtained in each stock-scion combination.

Even with large numbers this latter condition may not be fulfilled, owing to the effect of certain scions in altering the total size of the root system. For example in a series Cox and Bramley on No. IX., whilst twelve trees in the former gave total root weights between 21 and 40 gms. only two of the Bramley's fell within this range. On the other hand, fourteen Bramley's had root systems weighing over 50 gms. but no Cox had produced more than 50 gms. of roots. Unless, therefore, adequate numbers of trees are available, comparison is not a simple matter.

These considerations show that differences in percentage fibre may in part represent a difference in size of root systems, rather than a difference in character, when the total weights of roots differ. For example, in Tables I. and II. above, although in every case there is a significant difference in the percentage fibre as between No. II and No. VI, at the same time, in every case but one (Grenadier two years old) the group with the larger percentage fibre has the smaller root system. Moreover, when different varieties on a single stock are compared one with another, the same tendency is found, although with the smaller differences there are several exceptions. Thus it appears likely that the difference in total weight of roots may be responsible for a portion of the highly significant recorded difference in percentage fibre between II and VI, although this latter is so large compared with those shown in Table V, that there can be no doubt that the greater part of it is really an expression of the difference in fibrousness. This is made clear by the case of Grenadier two years old, in which the trees on stock No. VI were slightly larger on the average than those on No. II and at the same time had produced a higher percentage of fibre. A more striking example is found in Table IV in which trees on stock No. IX are smaller, whether Cox or Bramley is the scion, than those on No. I, and, at the same time, the latter show the higher percentage of fibre. In such cases, there can be no doubt that the whole of this difference is due to the difference of character between the two rootstocks and in fact it appears that had the total root weight of Cox on I and IX been more nearly equal, the percentages of fibre would have differed more widely.

So far, then, the results obtained with trees worked upon the stems of vegetatively propagated stocks, have shown that, although the character of a root system may be slightly influenced and its size considerably altered by the scion which it carries, yet the well known differences exhibited by unworked stocks are still unmistakably present in the worked tree, irrespective of the influence of the scion variety.

The comparison of stem-grafted and root-grafted trees is being dealt with in a further paper forming Part III of this series.

SUMMARY.

An extension of previous experiments which has involved the morphological analysis of various combinations (stem-worked) of six commercial scion varieties and four rootstocks has revealed the following features :—

1. In the maiden year the total weight of roots was characteristic of the stock rather than of the scion, although subsequently the effect of scion on the total size of the root system may be more marked. Grenadier at two years old, for example, induces the formation of a larger root system than other varieties compared with it, and incidentally shows a relatively high ratio of root to shoot.
2. Other factors being equal, a large root system has a lower percentage of fibrous roots than a small one.
3. Consequently the use of different scions may indirectly affect the percentage of fibre on the root by altering the size of the whole system.
4. The differences thus produced are small in comparison with the differences between the root-systems when unworked, and therefore the latter still unmistakably exhibit their distinctive varietal characters irrespective of the influence of the scion variety.
5. Thus the well marked qualitative differences between the rootstocks are still present in stem-worked trees and are not obscured by scion influence.

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(2) *East Malling Res. Sta. Ann. Rep. for* 1927 (May, 1928). Part I. Pomology, p. 38.

(3) *Swarbrick, T.,* and *R. H. Roberts.* The Relation of Scion Variety to Character of Root Growth in Apple Trees. *Univ. of Wisconsin, Agric. Exp. Sta. Research Bull.* 78. 1927.

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THE EFFECT OF SCION ON ROOT.*

III. COMPARISON OF STEM AND ROOT-WORKED TREES.

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A. INTRODUCTION.

In the experiment on the effect of scion on roots, described in 1923 in Part I. of this series (1), it was found that "though different scions may have different effects on the same stock, these seem to be, up to this age [one or two years] subordinate to the general root character."

The trees in that experiment were all stem-worked, in the manner usual in this country, and, as it is a common practice in some countries, notably America, to root-graft the scion direct on to piece roots of the stock, it was decided to extend the investigation to trees worked in the latter manner. A series of trees, therefore, were planted, made up of "two varieties grafted upon piece roots of two varieties of rootstock—to eliminate all stock stem." (3)

These trees were lifted in 1927, when they were three years old, but as reported in (3) p. 38, "unfortunately in all cases the scions—even of Bramley's Seedling—had themselves rooted so strongly that the original piece roots had become quite subordinate, and so they were useless for analysis of scion effect on root."

As mentioned in the same report, a new series of trees was set up that year (1927). This series was arranged so as to make it possible to compare the relative influence of scion and of stock and of the two different methods of working, i.e., stem-grafting on to rooted stems of stocks and root-grafting on to roots of stocks.

As the earlier attempts at grafting direct on piece roots had been vitiated by the rooting of the scion above the union, special care was taken to prevent all scion rooting. Planting was done so as to leave the unions well clear of ground level and in the early stages of growth the plants were earthed up slightly. When they had become established, the mound of earth was drawn away leaving the union exposed. This treatment was successful in preventing scion rooting.

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* For Parts I. and II. in this Series see "Literature cited" (1) and (2).

† Although it has fallen to the lot of the writer to analyse the results of this experiment and to prepare the paper, the experiment was planned by Mr. R. G. Hatton and Mr. J. Amos, and acknowledgments are also due to the propagation and recording staff of the Station for the careful detailed work involved in preparing the trees and in assisting in obtaining the data which are here discussed.

In view of the large number of batches required to include all possible combinations of the three potential sources of influence, the number of scion varieties and of types of rootstock were cut down as low as possible. Only two scion varieties, Beauty of Bath and Grenadier, therefore were used ; these being selected because the 1923 experiments (1) seemed to indicate that they showed extreme differences in scion effect on relative amount of root and relative amount of fibre. The two principal stocks used were Nos. II. and VI. because of the well-marked differences in their morphological characters. In addition, a certain number of Beauty of Bath were worked by both methods on No. VIII. ; unfortunately, however, heavy casualties reduced the number of these available for analysis.

For purposes of comparison, both scion varieties were also worked on one year old free seedlings. No seedling roots of sufficient diameter for piece root-grafting were available, hence the scions were grafted low on the main axis, as near as possible to the root system which was trimmed back to about six inches. Control batches were set up in which the varieties were stem-grafted on similar free seedlings with a length of the seedling stem left between the root system and the graft.

B. MATERIAL USED.

The series of trees used in this experiment is made up of eighteen different combinations of scion, rootstock, and method of working. A batch of each combination was lifted in December, 1929, when the trees were two years old, the remainder of the trees have been left *in situ* and records are being kept of their performance this year.

The make-up of the trees in each batch and the number of trees lifted are given in Table I (see page 277). Starting at the top of the table, the first two batches consist of unworked piece root cuttings of Nos. II. and VI. respectively, the next two of stems of Nos. II. and VI. each root-grafted on piece roots of the same variety. The next eight batches are made up of all possible combinations of two varieties of scion—Beauty of Bath and Grenadier, worked by two methods —root-grafting and stem-grafting, on to two types of rootstock—Nos. II. and VI. Next there are four batches made up of Beauty of Bath and Grenadier, worked as low as possible (Roots), or high (Stocks), on to root systems of one year old Free Seedling stocks. Finally, the last two batches in the table are composed of Beauty of Bath root-grafted on to piece roots and stem-grafted on to layers of No. VIII. Except in the last mentioned batch, which consisted of only six trees, the number of trees in each batch lifted was ten.

C. RECORDS TAKEN.

1. BASIS OF SYSTEM OF MEASUREMENTS.

The experiments described in Parts I and II of this series (1) and (2) have shown that the root-systems from stem-worked layered stocks of Nos. II. and VI. differ from one another in certain morphological characters which are almost independent of the variety used as scion; the main object of this experiment was to find out whether the root-systems of the two stocks retain these special characteristics when root-grafted piece roots are used instead of stem-worked layers, or whether, under these conditions, the morphological character of the root-system may be more markedly influenced by the variety used as scion.

The principal measurements made on the lifted trees were based, therefore, on the known morphological differences by which the root-systems of the two stocks Nos. II. and VI. can be distinguished. They were devised so as to express these qualitative characters as quantitative differences in size, weight and number.

The main differences between the two stocks are easily seen in Figs. 3 to 10 which illustrate typical trees of the various combinations, these differences, and the measurements made to express them quantitatively, may be summarized as follows:—

(i) In No. II. most of the roots arise from near the base, whilst in No. VI. they are more evenly distributed all the way up the underground portions.

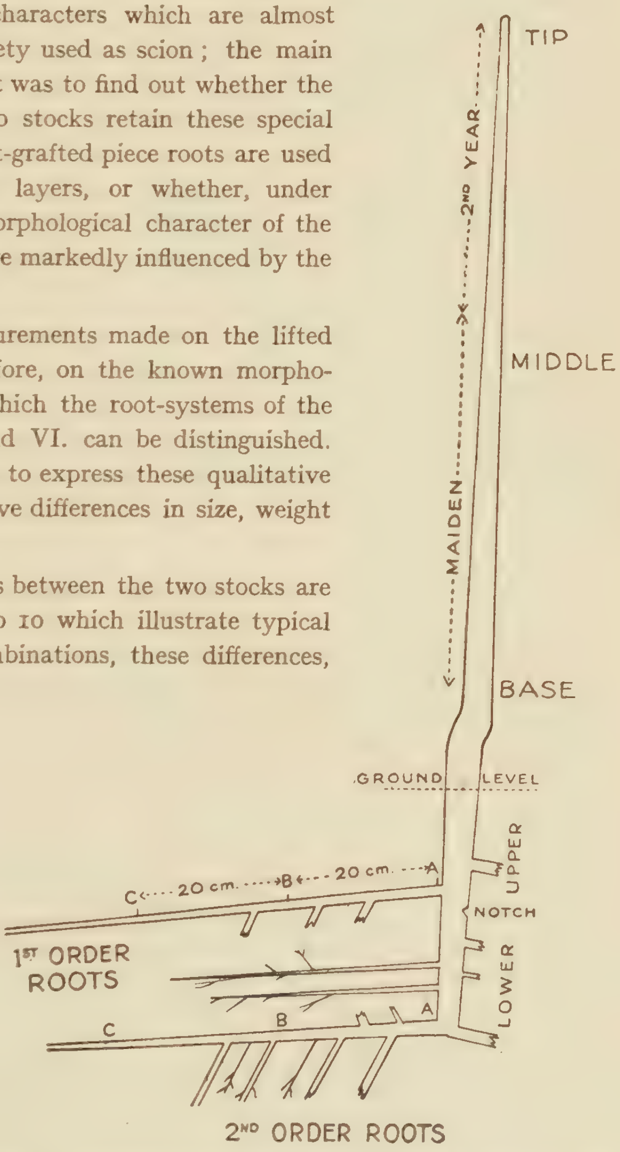

FIG. 1. Diagrammatic representation of tree to show records taken.

To get a quantitative expression of this character, the roots from the upper and lower halves of the underground portions were measured and weighed separately.

(ii) In No. VI. a large proportion of the smaller roots arise direct from the original or old wood of the stock, whilst in No. II. most of them arise from the stronger lateral roots. To express this feature in a quantitative manner, the roots were graded and counts made of the number of Grade II. roots, i.e., those more than 1 mm. but not more than 3 mm. in diameter, arising direct from the old wood (stem or root according to method of working), arising from the first 20 cm. and arising from the second 20 cm. respectively, of the stronger laterals.

(iii) There seemed to be some indication that the stronger roots of No. VI. tapered more rapidly than those of No. II. ; to determine if this was the case, the diameter of each of the Grade III roots, i.e., those more than 3 mm. in diameter, was taken at its point of origin (A) and at the distances of 20 cm. (B) and of 40 cm. (C) from the point. Analysis of the data for the unworked piece roots of No. II. and VI. and for the piece roots worked with stems of the same stocks as scions, has shown that the taper of the roots is practically identical in the two stocks, consequently it has not been considered worth while to analyse the data for the other batches with respect to this character.

2. FULL ROUTINE OF RECORDING, AND PRESENTATION OF RESULTS.

Most readers will find the headings and sub-headings in this section sufficient indication of the records taken. The full details of the technique elaborated are given in small type as they may be of value to those engaged in work along similar lines.

(*a*) *Records Taken Before Lifting.*

Measurements of Wood Growth. (Table II., p. 278.)

The Maiden Wood Growths were recorded in the winter 1928-9 and the 2nd Year Wood Growths in the winter 1929-30 ; the mean values of these measurements for the trees lifted are given in Table II. (p. 278), together with the summed total wood growths and the maiden wood growths expressed as percentages of these total wood growths.

(*b*) *Records Taken at Time of Lifting.* (*Vide* Diagram (1) and Fig. (1).)

The nature of these records will be best understood by examination of Diagram 1 and Figure 1. The one is a copy of the record sheet for one of the trees, the other a very diagrammatic representation of a tree.

Tree No. 40. Grenadier on VI. Stock.

STEM.	TIP.	MIDDLE.	BASE.	TOTAL WEIGHT OF CARCASE.
	5mm.	9 mm.	14 mm.	181 gm.

LENGTH BELOW GROUND. 13 cm.

ROOTS.	UPPER HALF.					LOWER HALF.						Grand Total.
Grade	No.	I	II.	III.	Total	Grade	No.	I.	II.	III.	Total	
I.	—	.4	—	—	.4	I.	—	1.0	—	—	1.0	1.4
II.	9	.7	1.4	—	2.1	II.	13	.8	1.3	—	2.1	4.2
III.	2	.2	3·1	3·3	6.6	III.	6	2·3	6.7	44·3	53·3	59·9
Total	—	1·3	4·5	3·3	9·1		—	4·1	8.0	44·3	56·4	65·5

DIAMETERS OF ROOTS.

		A.		B.	C.
		mm.		mm.	mm.
U.	1	6	4,	2	—
	2	3		2	—
L.	1	8		5	5
	2	6		3	—
	3	5	1,	—	—
	4	8		6	4
	5	9	2, 1,	—	—
	6	6	3, 3,	6	4

DIAGRAM (1).

Specimen of Record Sheet.

(*i*) *Stem Diameters and " Carcase " Weights.* (Table III., p. 279.)

The diameter of each stem was measured to the nearest mm. at the middle of the internode nearest to the following three points : (i) 5 cm. from tip, (ii) the middle of stem, (iii) 5 cm. from base. For the tree given as an example the values were 5 mm., 9 mm., and 14 mm. respectively. On the same line of the record sheet the total weight of the " carcase," that is of the tree after the removal of the roots, was later entered ; in the example this weight was 181 gm. The mean values of the diameters and " carcase " weights are given in Table III., p. 279.

(*ii*) *Distribution of Roots between Upper and Lower Halves.* (Tables IV. and V, pp. 279 & 280.)

The length of the underground portion of the old or original wood of the layer or root cutting was next measured and a notch cut at the middle point to divide the root system into upper and lower halves. These two portions were treated henceforward as separate units.

Counts were made of the number of 1st Order Grade II. roots, i.e., those more than 1 mm. but not more than 3 mm. in diameter at their point of origin from the old wood; in the example the numbers in the upper and lower halves were 9 and 13 respectively. The mean numbers of these 1st Order Grade II. roots are given in columns 1 and 3 of Table IV., their total number in Table VIII., column 1. The mean number in the upper half, expressed as a percentage of the total number, is given in column 3 of Table V. Counts were likewise made of the number of 1st Order Grade III. roots in the upper and lower halves, i.e., of those roots that were more than 3mm. in diameter at their point of origin from the old wood. In the example the numbers are 2 and 6 respectively. The mean numbers of Grade III. roots in the upper and lower halves are given in columns 5 and 7 of Table IV., p. 279, their combined number in column 1 of Table IX. The mean number in the upper half, expressed as a percentage of this total number, is given in Table V., column 5. The mean weight of the roots of all grades in the upper half, expressed as a percentage of the total weight (both halves), is given in column 1 of the same Table (V.).

(*iii*) *Relative Weights of Grade I. and Grade II. roots arising from the old wood and from branch roots respectively.* (Tables VII. and IX., pp. 281 & 282.)

Although it was not found practicable to count the number of Grade I. roots (those not more than 1 mm. in diameter) arising direct from the old wood of the upper and lower halves, their respective weights were obtained; in the example these were .4 gm. and 1.0 gm. These values were entered again in the columns headed " total " and summed in the column under " grand total " to the extreme right of the record sheet. The mean values for these grand totals are given in Table VII., column 1 and they have been expressed as percentages of the total root weight in Table IX., column 5.

After they had been counted the 1st Order Grade II. roots were subdivided into Grade I. and Grade II.; each root and branch root being cut at the point where it would just enter a slot exactly 1mm. wide. The weights of these two grades and their combined weight were entered in their appropriate places on the record sheet; in the example they are .7 and 1.4, giving a total of 2.1 in the upper, and .8 and 1.3, giving a total of 2.1 in the lower. The grand total is 4.2. The mean values of the Grade I. roots arising from the Grade II. are given in Table VII., column 3. The mean values of the grand totals for these Grade II. are given in column 7 of Table VII., these values have been expressed as percentages of the total root weight in Table IX., column 7.

The weights of 1st Order Grade III. roots were recorded in the same manner as those of Grade II., except that they had to be divided up into three grades instead of into two before weighing; the divisions being made at the points where the roots would just enter slots of 1 mm. and 3 mm. diameter respectively. The mean values of the weights of Grade I. roots, borne by these Grade III. branch roots, are given in column 5 of Table VII.

(*iv*) *Diameters of Grade III. Laterals of First Order.*

Before these Grade III. lateral roots were subdivided, certain other records were made on them:—The diameter of each was measured at three points; (A) as near as possible to the point of origin (B) 20 cm. and (C) 40 cm. from that point. These diameters were measured by the special grader described in the next section. The values of these diameters are given in the lower part of the record sheets, in the columns under A, B and C. In some cases no value is given for C or for B and C, this means that the root had come to an end before reaching a length of 40 or 20 cm. respectively, or had been broken off during the process of excavation.

(*v*) *Number and Diameter of Grade II. and III. Roots of Second Order.* (Tables VIII. and IX., p. 282.)

The diameter was taken at point of origin of every lateral root of the 2nd order arising from regions AB (1st 20 cm.) and BC (2nd 20 cm.) of the Grade III. roots of the 1st order. These diameters were measured to the nearest millimetre by means of the special grader illustrated in Fig. 2. This grader, devised by Mr. Rogers, was made out of three strips of steel bolted on to a base plate in such a way as to leave tapering spaces between them. Graduation marks engraved on the arms gave the diameter of the spaces at different points. Those for the small space ranged from 1 mm. to 11 mm.; those for the wider space from 10 mm. to 20 mm. In each case the intervals between successive diameters was 1 mm. and the taper was so adjusted that graduation marks were 1 cm. apart on the steel arms. For the purpose of grading, each root was placed in the appropriate tapering space and allowed to descend towards the narrower end until it would go no further without pressure; the graduation mark nearest this point was taken as the diameter of the root.

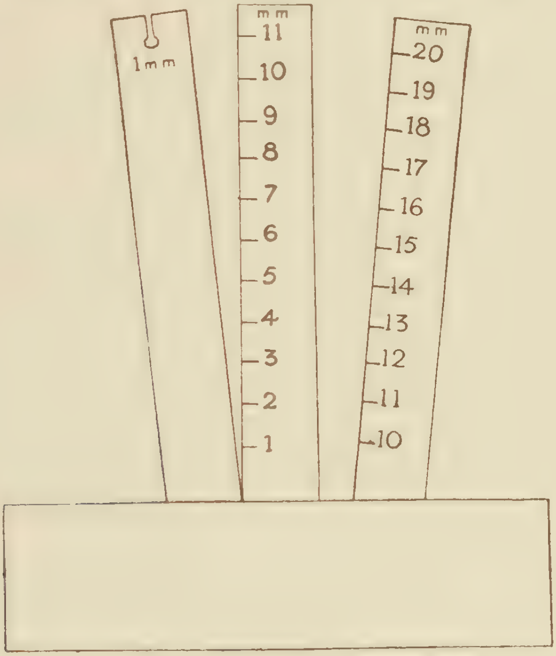

FIG. 2. "Taper" Grader.

The mean number of the 2nd order Grade II. roots rising respectively from the 1st 20 cm. (AB) and the 2nd 20 cm. (BC) of the 1st Order Grade III. are given in columns 3 and 5 of Table VIII. The mean total number of Grade II. (1st and 2nd Order) are given in column 7 of the same table. The numbers of 2nd Order Grade III. from the region BC were too few to be worth analysing, but those from the region AB are given in Table IX., column 3.

(*vi*) *Total Weights of Trees (Table I.) and of Roots (Table VI.).*

The mean total weights of the roots (all grades) are given in Table VI., column 3; those of Grade I. and II. (all orders) in columns 1 and 2 of the same table. The total weight of Grade I. and the summed weights of Grades I. and II., expressed as percentages of the total root weight, are given in columns 5 and 6 of the same Table (VI.). Finally the mean total weights of the tree, i.e., the combined weights of " carcase" and roots, are given in column 5 of Table I., and the total root weight, expressed as a percentage of this total tree weight, in column 7 of the same table.

D. METHOD OF ANALYSIS OF RESULTS.

(1) Calculation of Significance of Difference Between Mean Values for Two Batches.

The mean values of the various batches with respect to the principle characters of root, shoot, and tree as a whole have been given in the Tables (pp. 277, 282), but to bring out the relative influence of variety used as scion, of rootstock and of method of working, upon these characters, further analysis has been necessary.

The method of analysis adopted has been to arrange the batches in pairs and to determine the significance of the differences between the mean values for the two members of each pair by the method described in Fisher's " Statistical Methods " (4) S 24.1, p. 107.

With a few exceptions, which will be indicated in the detailed description that follows, the batches were paired so that the two members of each pair differed from one another with respect to one only of the three possible sources of influence —scion, stock and method of working.

For example, the batch BB.II.R. (Beauty of Bath on Stock No. II., root-grafted) has been paired with BB.II.S. (Beauty of Bath on Stock No. II, stem-grafted) from which it differs only with respect to method of working, with Gr.II.R. (Grenadier on Stock No. II. root-grafted) from which it differs only with respect to the variety used as scion, and with BB.VI.R. (Beauty of Bath on Stock No. VI. root-grafted) from which it differs only with respect to the type of rootstock used.

No useful purpose would be served by determining the significance of a difference between a pair of batches such as BB.II.S. and Gr.II.R., because there would be two possible sources of influence, scion variety and method of working, and it would be impossible to decide to which of these a significant difference was due.

(2) Explanation of Charts.

The significance or otherwise of the difference between the two members of various pairs of batches with respect to the mean values of the more important characters of root, stem and of the tree as a whole, has been worked out and summarized in Charts 1-3.

The headings of the columns in the Charts refer to these characters, and are the same in each Chart. For the sake of easy cross reference the table and column where the actual mean values of the data from which the significances have been calculated may be found, has been entered at the base of each column, for example, *I. 5* at the base of the first column denotes that the mean values of the total tree weights will be found in Table I. column 5.

The horizontal rows refer to the pairs of batches compared; for example, the top row of Chart I., BB.II. (**R. & S.**) refers to the pair of batches BB.II.R. and BB.II.S. which consist of the same scion, Beauty of Bath, on the same rootstock No. II., but differ in that the one was root-grafted on to piece roots and the other stem-worked on to layered stocks. For the sake of economy of space in the chart, BB.II., the part of the title common to both batches, has been printed only once; whilst for emphasis, **R. and S.**, the parts of the titles descriptive of the difference between the two batches, has been printed in Clarendon type. Similarly, in the top row of the middle third of Chart I. (**BB. & Gr.**) II.R. denotes the comparison between the pair of batches, BB.II.R. and Gr.II.R.; **BB.** and **Gr.** being in Clarendon type because these two batches differ only with respect to variety used as scion. In the same way BB.(**II. & VI.**) R. at the top of the lower third of the same chart denotes the comparison between the pair of batches BB.II.R. and BB.VI.R. which differ only in respect to rootstock.

A significant difference between the two members of a pair with respect to one of the root, shoot or tree characters, is denoted in the appropriate column by the distinctive symbol of the batch with the significantly higher mean value, e.g., the symbol **S.** at the point of intersection of the column I. 7 (Root weight as percentage Total Weight) and the row BB.II.(**R. & S.**), denotes that the batch BB.II.S. had a significantly higher mean value than the batch BB.II.R. for the root weight as percentage total weight.

E. DISCUSSION OF RESULTS.

(I) BEAUTY OF BATH AND GRENADIER ON NUMBERS II. AND VI. (*Vide* Chart I.)

The eight batches of trees made up of all possible combinations of the two varieties of scion (Beauty of Bath and Grenadier), worked by the two methods, (root-grafting on to root-cuttings and stem-grafting on to layered stocks), on to the two types of stock (Nos. II. and VI.) can be arranged in pairs in three ways. This has been done in Chart I.

In Section A. (the upper third of Chart I.), they are arranged so that the two members of each pair differ only with respect to method of working; e.g., BB.II.R. and BB.II.S.

In Section B. (the middle third of the Chart), they are arranged so that the two members differ only with respect to scion variety; e.g., BB.II.R. and Gr.II.R.

In Section C. (the lower third of the Chart) they are arranged so as to differ only with respect to stock, e.g., BB.II.R. and BB.VI.R.

Thus the significant differences shown in the Chart may be regarded as the direct or indirect result of (a) method of working in Section A. (b) variety used as scion in Section B., and (c) rootstock in Section C.

(a) *Influence of Method of Working ; Root-grafts on Piece Roots and Stem-grafts on Layers.*

This is summarized in Section A. (the upper third of Chart 1.).

(i) *Tree Characters.*—There were no significant differences in either total weights of tree or in carcase weights and there is no consistency about such differences as there were ; sometimes the root-grafted batch and sometimes the stem-grafted batch was the heavier. The Total Root Weight was consistently lower in the root-grafted batches, but in only one case was the difference significant ; expressed as a percentage of the total tree weight, however, it was significantly lower in three out of the four pairs.

(ii) *Stem Characters.*—The maiden wood growth was always less and the second year growth always more in the root—than in the stem-grafted trees, but the differences were mostly very small and in all cases but one (BB.VI.R. & BB.VI.S.) insignificant. This one exception is reflected also in a significant difference in the maiden growth as a percentage of total growth. The differences in total wood growth were neither significant nor consistent. In this same pair the root-grafted batch has a significantly greater stem diameter 5 cm. from tip than the stem-grafted batch ; there were no other significant differences in diameter.

(iii) *Root Characters.*—The combined percentage of Grades I. and II. was significantly greater in the root-grafted than in the stem-grafted member of the pair Grenadier on No. II., this was probably merely a reflection of its significantly smaller amount of root ; for in general the smaller the root system, the higher the percentage fibre. There were no other significant differences with respect to this character. In no case was there a significant difference in the percentage of roots in the upper half or in the percentages of root arising as Grade I. or Grade II. from the old wood of root cutting or stock.

In every case the root-grafted batches had the smaller number of Grade II. and Grade III. arising from the old wood, and in most cases the differences were significant. This can hardly have been a mere reflection of the smaller size of the root systems, for in most cases the number of these roots arising as branches of the second order from the Grade III. laterals were greater and sometimes significantly greater in the root-grafted batches. It would seem, therefore, that roots arise more freely adventitiously from the stem wood of layered stocks than from the old wood of root cuttings.

In General, the effect of method of working may be briefly summarized as follows :—It had no significant effect on the weight of tree or of carcase, little on stem characters and none on the distribution of the roots between upper and lower halves. The number of first order Grade II. and III. roots and the total weight of roots was greater in the trees on layered stocks than in the corresponding trees worked on piece roots.

(b) *Influence of Scion Variety ; Beauty of Bath and Grenadier.*

This is summarized in Section B. (the middle third of Chart I).

(i) *Tree Characters.*—There were no significant or consistent differences in total weights of trees or in carcase weights. The total weight of roots, however, was consistently and usually significantly greater in Grenadier; the root weight expressed as a percentage of total weight always significantly greater. This bears out observations already made at this Station (1).

(ii) *Stem Characters.*—In only one pair (**BB. and Gr.**) VI.R., was there a significant difference in wood growth, here the Beauty of Bath made less maiden growth but more second year growth than Grenadier.

As might be expected, the stem diameters were largely influenced by the variety used as stem ; in every case the diameter 5 cm. from the tip was significantly greater in Grenadier than in Beauty of Bath.

(iii) *Root Characters.*—The percentages of Grades I. and II. were usually larger in Beauty of Bath than in Grenadier, this was probably a reflection of the smaller total amount of root ; for the only pair of batches that showed no significant difference with respect to this character was also the only one that showed no significant differences in total root.

There was no significant difference in the distribution of roots between upper and lower halves.

The significant differences in percentage of 1st Order Fibre correspond exactly to those for the total fibre expressed as percentages of total weight of roots. As the number of Grade II. roots was never significantly greater and sometimes significantly less, these higher percentages may be regarded as the outcome of the smaller size of the root system rather than due to a difference in distribution within it. Moreover the number of Grade III. roots arising direct from old wood was usually significantly less in Beauty of Bath, there were fewer of these, therefore, from which Grade I. and II. roots of the second order could arise; this may account for the *proportion* arising from old wood being greater.

(iv) *In General, there were no significant differences in total size of tree or of " carcase " between Beauty of Bath and Grenadier, worked by the same method on to* *the same two stocks. In each case, however, Beauty of Bath had a lower proportion of roots and this was associated with a lower number of Grade III. roots and a higher percentage of roots of lower grades. Variety had apparently no direct effect upon the distribution of roots, only effecting this distribution indirectly through its direct influence on total root weight.*

(c) *Influence of Rootstock ; Number II. and Number VI.*

This is summarised in Section C. (the lower third of Chart 1).

(i) *Tree Characters.*—Again there were no significant or consistent differences in tree weight or in carcase weights. There were likewise no consistent differences in total root weights or in root weights expressed as percentages of the total weight of tree; where the scion was Beauty of Bath the roots were actually and relatively heavier on II. than on VI., whilst the reverse was the case when the scion was Grenadier. In only one case was a difference significant.

(ii) *Stem Characters.*—The maiden wood growth was usually less on II. than on VI., and where the scion was Grenadier, significantly less ; those on II., however, grew away in their second year, for the wood growth in that year was consistently greater though never significantly greater. With one exception, the stock had no significant effect on stem diameter.

(iii) *Root Characters.*—The type of rootstock had profound and consistent effects on the character of the distribution of the roots within the root system, and these effects cannot have been the result of differences in total root weight for the differences between those on No. II. and those on No. VI. were of the same kind, whether the former or the latter had the greater amount of root.

The percentage of fibre was always smaller, and often significantly so, when the rootstock was No. II. It was, however, in the distribution of the roots between the upper and lower halves and between branch-roots of different orders that the differences were most marked. The percentage of the total weight and of the number of first order Grade III. roots in the upper half was always significantly greater in No. VI. than in No. II. The percentage of the number of first order Grade II. roots in that half was likewise consistently larger and sometimes significantly so. It has been pointed out already that neither the method of working nor the variety used as scion had any significant effect on this distribution of roots between upper and lower halves.

The number of first order Grade II. roots, i.e., those arising direct from the old wood, was always significantly higher in No. VI. and the number of second order Grade II. arising from the first 20 cm. of Grade III. roots always significantly higher in No. II.

In General, there was no consistent or significant difference in total weight or " carcase " weight between the trees on the two stocks and little, if any, in stem

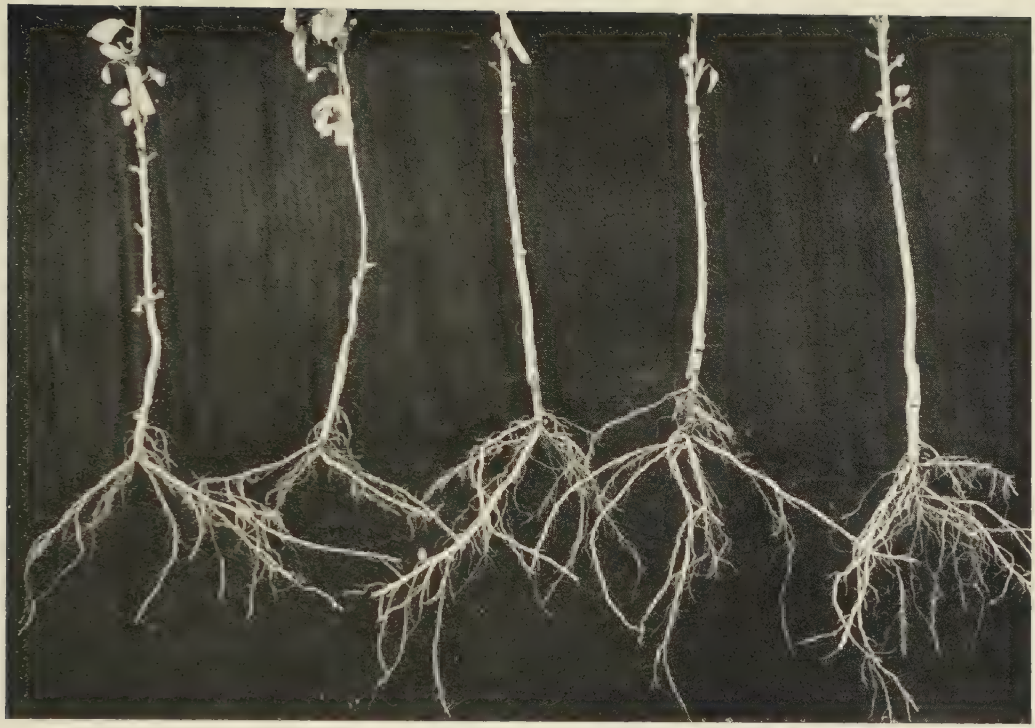

FIG. 3.
Typical two year Beauty of Bath grafted on to Stems of No. II. rootstock.

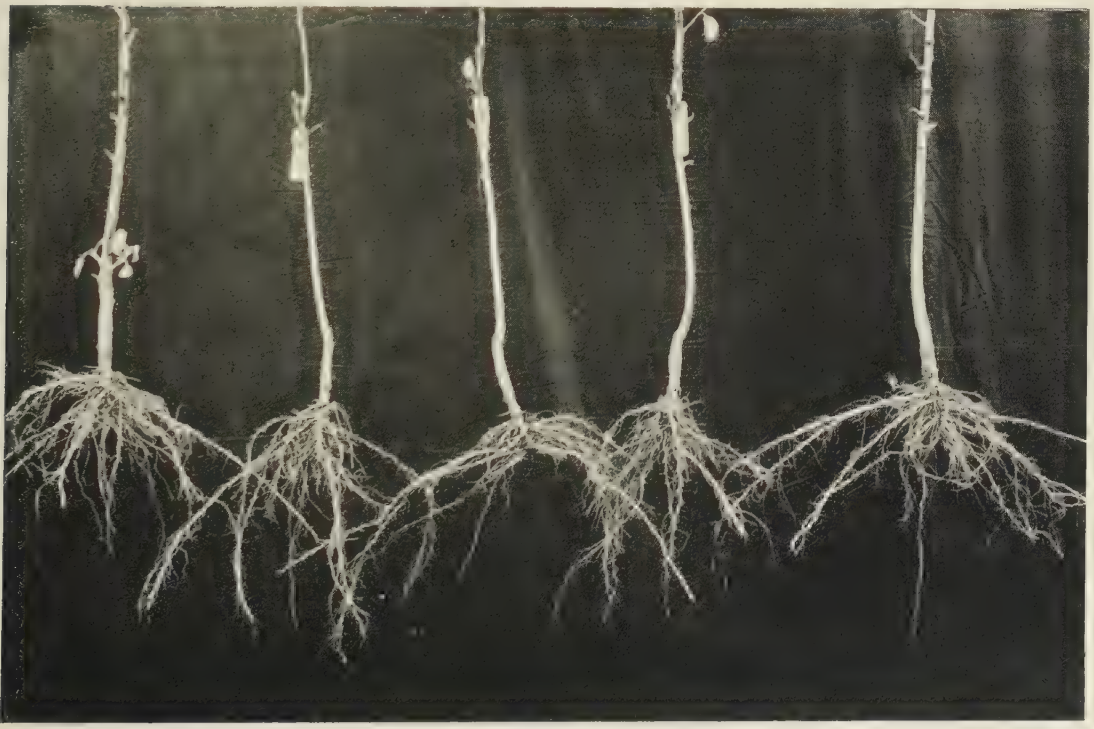

FIG. 4.
Typical two year Beauty of Bath grafted on to Stems of No. VI. rootstock.
Note that No. II. is more basal rooting than No. VI. and No. VI. has more fibre arising from old wood.

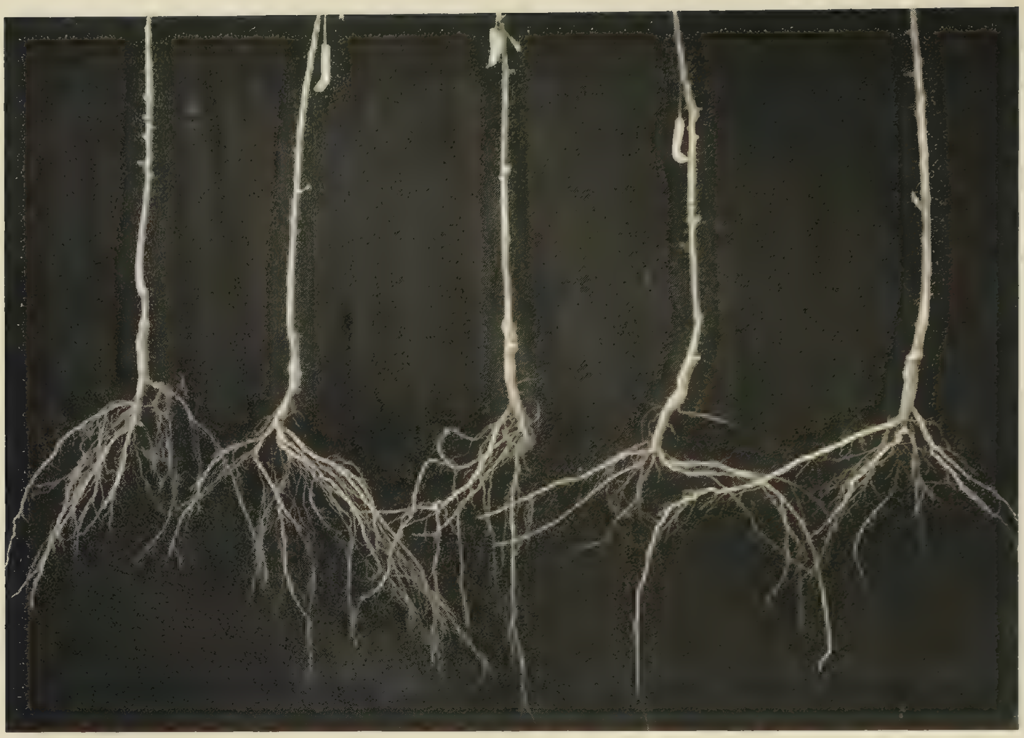

FIG. 9.
Typical two year Grenadier grafted direct on to piece roots of No. II. rootstock

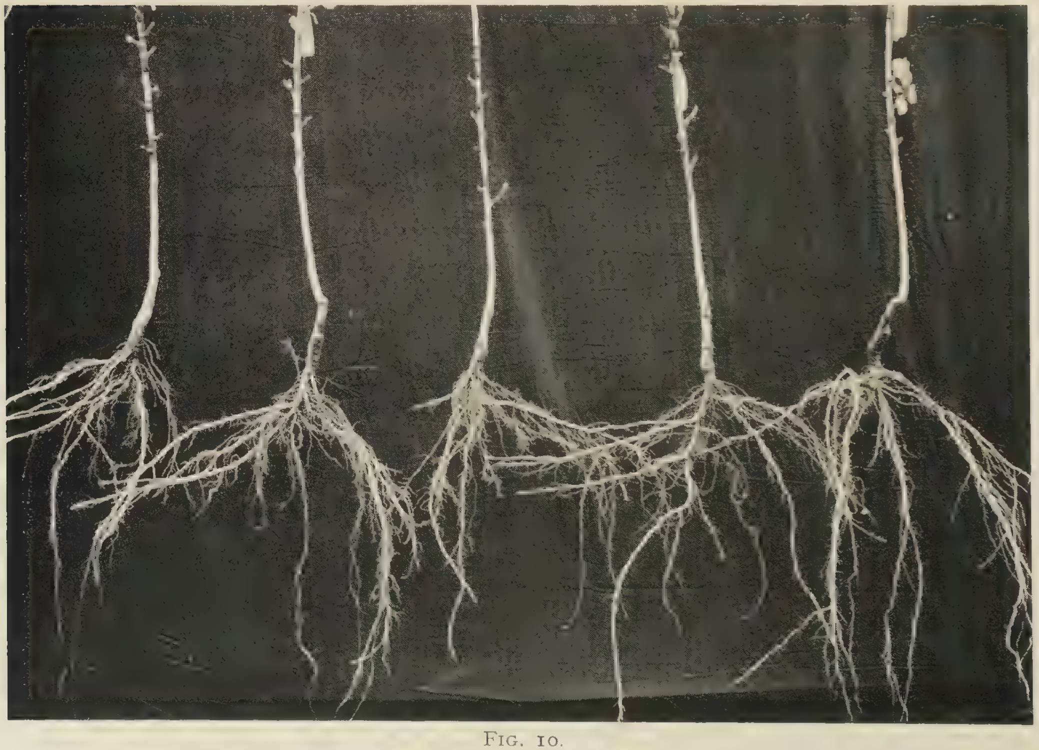

FIG. 10.
Typical two year Grenadier grafted direct on to piece roots of No. VI. rootstock.
Note that the differences between the root-systems of the two stocks are the same here where piece roots were used, as in Figs. 7 and 8 where stems were used.

character. There were no consistent differences in the total weight of roots but there were profound and significant differences in the morphological or qualitative root characters. The morphological differences between the two rootstocks were the same whichever variety was worked on them and whichever the method of grafting.*

(2) NUMBERS II. AND VI. STEMS ON THEIR OWN ROOTS.

(*Vide* Chart 2, Sections D. and E.)

The batches of No. II. and No. VI. root cuttings unworked and those root-grafted, using stems of the same stock types as scions, are compared in the upper part (D. and E.) of Chart 2.

There are two ways in which these four batches can profitably be paired; (a) to show effect of method of working, e.g., II. unworked versus II.II.R. and (b) to show combined influence of stock and scion, e.g., II.II.R. versus VI.VI.R., There is no way of distinguishing between the effects of stock and scion because the combinations II.VI.R. and VI.II.R. were not represented in the series.

(a) *Influence of Method of Working: Unworked and grafted piece roots.*

(Chart 2, Section D.)

The root-grafted piece roots are here compared with unworked root cuttings, and not with stem worked layered stocks as in Chart 1. The comparisons here made are therefore not similar to those made in Section A. The unworked root cuttings of No. II. made smaller trees but had more roots than those grafted with No. II. These differences were not significant, their combined effect, however, was a significant difference in root weight expressed as a percentage of total weight. The stem diameter at 5 cm. from the tip was significantly greater in the worked cuttings; there were no other significant differences between the two batches.

The unworked root cuttings of No. VI. produced much smaller trees than No. VI. grafted with No. VI.; the carcase, the root and the total weights were all significantly smaller. These differences were due to very weak growth during the maiden year since the wood growth in the second year was actually significantly greater in the unworked batch. The significantly higher values for the total percentage of fibre, for the percentages of first order Grades I. and II., and for the number of Grade II. roots of the first order, were probably mere reflections of the smaller total amount of root.

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* It may be well to state that rootstock No. II. is described in general as " semi-dwarfing " though it is known to bring some varieties into the " vigorous " class. No. VI. is in general a " vigorous " stock.

(b) *Combined Influence of Stock and Scion : No. II. versus No. VI.*

(Chart 2, Section E.)

(i) *Tree Characters.*—Number II. always gave a significantly higher carcase weight and total tree weight than No. VI., but as the total root weight was likewise greater, the relative amount of root was not significantly different.

(ii) *Stem Characters.*—As might be expected, these characters were largely influenced by the variety used as scion. The wood growth was consistently greater in No. II. than in No. VI., and the differences usually significant ; the diameters 5 cm. from tip were always significantly less in No. II.

(iii) *Root Characters.*—It is the difference between the morphological characters of the root-systems that is of greatest interest. In spite of the large quantitative differences in total amount of root, the two stocks showed exactly the same qualitative dissimilarities here as they did when worked with Beauty of Bath or Grenadier.

No. II. had lower percentages of roots in the upper half, a lower percentage of root rising as Grade I. from old wood, fewer first order Grade II. roots but more second order Grade II. from the first 20 cm. of Grade III. These differences were always significant. The number of Grade III. roots of the second order was likewise significantly greater in No. II. than in No. VI.

(3) BEAUTY OF BATH AND GRENADIER COMPARED WITH NOS. II. AND VI. USED AS SCIONS.

(Chart 2, Section F.)

These four pairs, given in the centre of Chart 2, complete the analysis of the relative effect of scion and stock on tree, stem and root characters of trees on roots of Nos. II. and VI. The results summarized in the table are self-evident and need not be described in detail. There were few significant differences in tree characters, many in stem characters, but practically none in root characters. In other words, the root-system of a No. II. worked with either Beauty of Bath or Grenadier, did not differ significantly from that worked with No. II. itself. Similarly the root-system of a No. VI. worked with either of the same two varieties showed no significant differences from one of the same stock worked with No. VI.

It has thus been shown so far that there are marked significant differences of a qualitative character between the root-systems of Numbers II. and VI., and that these differences are the same whether both root-systems are worked with Beauty of Bath or with Grenadier, or whether both are left unworked or worked with stems of their own stock variety as scions. It is very clear, therefore, so far as these two stocks and these two varieties are concerned, that the general morphology of the root-system *is dependent on the type of stock used and independent both of variety used as scion and of method of working.*

(4) BEAUTY OF BATH ON ROOTSTOCKS NOS. II., VI. AND VIII.

(Chart 2, Section G. and H.)

The lower part of Chart 2 summarizes the results of comparing with one another the batches of trees worked by different methods on rootstock No. VIII., and of comparing each of these with batches similarly worked on Nos. II. and VI.

(a) *Influence of Method of Working: Root-grafts and Stem-grafts.*

(Section G.)

Here the difference in method of working is the same as that in Chart 1, Section A., i.e., one batch was root-grafted on to piece roots, the other stem-grafted on to layered stocks.

Except for a higher percentage of Grade II. roots in the upper half in the case of the root-grafted batch, there was no significant difference between these two batches in any tree, stem or root character.

(b) *Influence of Scion Variety,* cannot be determined as Beauty of Bath was the only variety used as scion on the No. VIII. stocks.

(c) *Influence of Rootstocks.* (Section H.)

(i) *Tree Characters.*—The total tree weight and the carcase weight was always greater in Nos. II. and VI. than in No. VIII.; this might be expected as No. VIII. is a very dwarfing stock. In only one pair, however, was the difference significant.

(ii) *Stem Characters.*—Rootstock seems to have had little influence on the stem characters of Beauty of Bath.

(iii) *Root Characters.*—The root-systems of the trees on No. VIII. differed significantly from those on No. II. in their percentage of total fibre and from those on No. VI. in the percentage of roots in the upper half, and consistently, though not always significantly, from both stocks in the number of Grade II. roots arising from the first 20 cm. of Grade III. roots. There was no significant difference in the number of Grade III. roots.

(5) BEAUTY OF BATH AND GRENADIER ON FREE SEEDLINGS AND ON STOCKS NOS. II., VI. AND VIII.

(Chart 3.)

The results of these comparisons are summarized in Chart 3.

The two methods used were (1) Free Seedling rootstocks grafted as low as possible, so as to have a minimum of seedling stem between the roots and the scion (F.R.) and (2) Free Seedling rootstocks grafted in the normal way just above ground (F.S.). The former method is not strictly comparable with the bench grafted root cuttings of Nos. II., VI. and VIII., for the scions were worked on to a root-system composed of several roots instead of on to a single piece of root. The seedlings worked high (F.S.) more nearly resemble those on layers, but again there was some difference in treatment ; the layered stocks had all their roots removed at the time of planting, whilst those of the seedlings, whether worked high or low, were merely trimmed to about 6 inches. It was not difficult to distinguish between the " old wood " or root present at the time of planting, and the new roots that had arisen since ; but occasionally some of the new roots had become pressed and fused to the old wood and interpretation was difficult.

(a) *Influence of Method of Working Free Seedlings : High and Low.*

(Chart 3, Section J.)

(i) *Tree Characters.*—The carcase weights and tree weights were consistently, and in one pair significantly, less in the batches worked low (F.R.) ; this is to be expected for these were less by a length of stock stem at time of planting than those worked high. The lower tree weight resulted in a higher percentage of root, though the actual weight of new roots did not differ consistently or significantly in the two cases.

(ii) *The stem characters* were little affected.

(iii) *The Root Characters.*—Trees on Seedling roots had less root in the upper half, and fewer first order roots of all grades than those on seedling stocks.

(b) *Influence of Scion. Beauty of Bath versus Grenadier.*

(Chart 3, Section K.)

The differences are much the same as those between the varieties when worked on Nos. II. and VI. Beauty of Bath had the smaller root system, a higher percentage of small roots of the first order of branching and fewer of the second order.

(c) *Influence of Rootstock : Free Seedlings and Stocks Nos. II., VI. and VIII.*

(Chart 3, Section L.)

(i) *Tree Characters.*—The batches on vegetatively raised stocks had consistently, and often significantly, smaller total tree weights and carcase weights. The total root weights were often significantly smaller too, but the root weights expressed as percentages of the total tree weights showed no consistent, though many significant, differences.

(ii) *Stem Characters.*—The maiden wood growth and the total wood growth was always less on the vegetative stocks, and often significantly so. The differences in second year growth were neither consistent nor significant. There were not many significant differences in diameter, in a few cases those on vegetative stocks were thicker at the tip, and in two cases they were thinner at the base.

(iii) *Root Characters.*—The root systems of the seedling stocks differed widely and very significantly from those of both No. VI. and No. VIII., but less significantly and less consistently from those of No. II. In the case of Nos. VI. and VIII., the differences were of the same kind whichever the variety used as scion and whichever the method of working.

General.—The root-systems of heterogeneous free seedlings, worked with Beauty of Bath or Grenadier, failed to take on distinctive morphological characters according to the variety used as scion. The scion, moreover, showed no greater influence on root character when it was root-grafted direct on to the root-system than when an intermediate piece of stock stem was left below the union.

F. GENERAL CONCLUSIONS.

Former experiments, already described in previous papers from this Station, have shown that the root-systems of clone stocks, such as No. II. and No. VI., when stem-worked with scion varieties, such as Beauty of Bath and Grenadier, retain each its own distinctive morphological characters approximately constant, irrespective of the variety used as scion, although the scion variety may have a marked influence on the quantity of roots and hence have some indirect effect on the relative amounts of large and small roots.

The experiment described in the present paper confirms this conclusion and extends it to include cases where the scion variety has been root-worked on to piece roots of the stocks instead of stem-worked on to rooted stems.

In this experiment, too, the root-systems of heterogeneous free seedling stocks, worked with Beauty of Bath or Grenadier, failed to take on distinctive morphological characters according to the variety used as scion, whether that variety was grafted direct on to the root system, or stem-grafted with a length of stock stem left below the union.

Thus the scion failed to change the distinctive characters of the root-systems of vegetatively propagated clone stocks and failed to impart distinctive characters to the root-systems of heterogeneous seedlings. These conclusions are not in agreement with the observations recorded by Swarbrick and Roberts (5) that " clearly indicate that the scion variety strikingly influences root anatomy when the graft is placed directly upon the root, and that the root structure is relatively little affected if there is an intermediate piece of stem between the root proper and the scion " (l.c., p. 18), and their suggestion that " this is an indication if not an explanation of why trees grown under American nursery conditions strikingly modify the root character but do so to a very limited degree under English propagation methods " (l.c., p. 19).

It must be remembered, however, that the varieties used as scion and the age of the trees were not the same in the two cases.

Further work must be carried out with older trees and with other stocks and scions before it can be decided how far these conclusions are of general application.

G. SUMMARY.

The distinctive characters of the root-systems of two year old No. II. and No. VI. stocks remained approximately constant whether unworked, worked with scions of their own variety or with Beauty of Bath or Grenadier and whether the latter were root-grafted on to piece roots or stem-grafted.

No. VIII. worked with Beauty of Bath was likewise little affected by the method of working.

Root-systems of free seedling stocks failed to take on distinctive characters when worked with Beauty of Bath and Grenadier respectively whether or not a length of stock stem was left below the graft union.

Grenadier always gave a relatively larger root-system than Beauty of Bath and, in consequence, a smaller percentage of fibre.

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(5) *Swarbrick, T.,* and *R. H. Roberts.* The Relation of Scion Variety to Character of Root Growth in Apple Trees. *Univ. of Wisconsin Agric. Expt. Sta. Res. Bull.* 78. 1927.

TABLE I.

Explanation.—"Roots" denote that the scions were grafted direct on piece roots in case of Stocks Nos. II., VI. and VIII., or on root-systems in the case of the Free Seedlings. "Stocks" denote that they were stem-worked on layers of stocks Nos. II., VI. and VIII. or on the stems of the Seedlings. For full explanation *vide* text, B., p. 260.

Variety.	Stock.	Method of Working.	Number of Trees.	Total Weight of Tree.		Root Weight as Percentage of Total Weight.	
				Mean.	S.E.	Mean.	S.E.
II.	Unworked.		10	215.3	32.3	22.6	1.71
VI.	Unworked.		10	118.1	17.7	20.4	.67
II.	II.	Roots.	10	239.0	15.2	17.0	1.02
VI.	VI.	Roots.	10	194.7	12.9	18.5	1.00
Beauty of Bath ..	II.	Roots.	10	253.6	25.3	14.1	.86
Beauty of Bath ..	VI.	Roots.	10	190.0	23.8	15.7	1.03
Grenadier	II.	Roots.	10	215.3	19.3	20.3	1.38
Grenadier	VI.	Roots.	10	237.0	25.3	25.2	1.19
Beauty of Bath	II.	Stock.	10	211.1	24.2	20.3	1.21
Beauty of Bath	VI.	Stock.	10	207.4	26.9	17.7	.89
Grenadier	II.	Stock.	10	221.8	13.8	27.7	1.00
Grenadier	VI.	Stock.	10	228.0	17.0	28.4	.82
Beauty of Bath	Free Seedlings.	Roots.	10	312.1	38.6	20.4	.79
Grenadier		Roots.	10	283.5	37.7	30.2	1.05
Beauty of Bath ..		Stock.	10	324.5	32.0	15.5	1.20
Grenadier ..		Stock.	10	404.6	24.4	24.7	1.08
Beauty of Bath ..	VIII	Roots.	10	162.9	17.5	16.9	1.35
Beauty of Bath ..	VIII	Stock.	6	156.2	11.6	20.5	2.20
Column 1	2	3	4	5	6	7	8

Table II.

F.R. denotes that scion was worked as low as possible on Free Seedling root-systems ; F.S. that it was worked higher on similar Seedlings, i.e., with a length of seedling stem left between root-system and the graft.

Variety, Stock, Method of Working.	Wood Growth Measurements in cm.						Maiden as Percentage of Total.	
	Maiden. 1928.		2nd Year. 1929.		Total.			
	Mean.	S.E.	Mean.	S.E.	Mean.	S.E.	Mean.	S.E.
II. R. Unworked	49·7	6·16	72·3	6·17	122·0	12·18	39·3	3·91
VI. R. Unworked	25·4	5·68	67·0	2·86	92·4	5·78	25·0	4·79
II. II. R. ..	54·8	4·06	80·0	4·16	134·8	5·97	40·6	1·93
VI. VI. R. ..	46·5	1·64	55·0	3·78	101·5	4·15	46·3	1·87
BB. II. R. ..	45·7	6·06	82·7	3·27	128·4	7·10	34·2	3·55
BB. VI. R. ..	45·0	4·62	85·0	5·60	130·0	8·46	34·3	2·42
Gr. II. R. ..	40·2	6·81	73·2	5·41	113·4	4·52	34·6	5·49
Gr. VI. R. ..	58·0	2·40	69·0	4·50	127·0	4·63	46·1	2·26
BB. II.S. ..	45·9	5·70	74·5	4·33	120·4	6·81	37·3	3·69
BB.VI.S. ..	61·7	5·05	68·3	5·54	130·0	9·28	47·6	2·28
Gr.II.S. ..	43·7	2·52	71·5	2·87	115·2	3·08	37·9	2·07
Gr.VI.S. ..	59·6	2·26	66·5	4·40	126·1	5·85	47·7	1·52
BB.F.R.	77·6	7·89	77·3	3·40	154·9	8·62	49·0	3·25
Gr.F.R. ..	61·9	8·46	64·9	7·22	126·8	9·27	48·2	6·49
BB.F.S.	73·2	4·87	78·6	2·33	151·8	4·95	47·7	1·70
Gr.F.S.	83·5	2·68	63·9	4·82	147·4	6·50	57·3	1·93
BB.VIII.R. ..	41·2	5·50	75·9	2·96	117·1	5·50	34·1	3·40
BB.VIII.S. ..	40·8	7·67	66·5	9·64	107·3	4·78	38·7	7·54
Column ..	1	2	3	4	5	6	7	8

TABLE III.

Variety, Stock, Method of Working.	Stem Diameters in mm.						Weight of "Carcase."	
	Tip.		Middle.		Base.			
	Mean.	S.E.	Mean.	S.E.	Mean.	S.E.	Mean.	S.E.
II.R.Unworked ..	3.5	.267	8.75	.726	13.1	1.06	168.3	26.03
VI.R.Unworked ..	5.5	.500	8.2	.611	10.6	.764	94.4	14.26
II.II.R. ..	4.2	.133	9.8	.289	12.4	.400	198.3	13.12
VI.VI.R. ..	6.7	.300	10.1	.277	12.9	.433	159.4	12.06
BB.II.R. ..	4.0	.148	9.7	.396	14.2	.646	217.9	22.38
BB.VI.R. ..	3.8	.133	8.7	.496	12.4	.792	161.0	21.01
Gr.II.R. ..	5.2	.133	9.4	.499	12.1	.433	170.5	14.71
Gr.VI.R. ..	4.8	.160	8.9	.433	12.8	.345	176.9	10.30
BB.II.S.	3.8	.133	8.9	.433	13.7	.731	170.1	21.29
BB.VI.S... ..	3.1	.100	8.9	.504	13.8	.840	170.5	22.06
Gr.II.S. ..	5.1	.179	9.3	.300	12.9	.315	159.9	8.92
Gr.VI.S. ..	4.6	.221	8.8	.291	13.7	.496	162.5	10.84
BB.F.R.	3.3	.281	9.9	.700	14.6	.806	248.7	31.75
Gr.F.R. ..	3.9	.233	8.4	.718	12.8	1.104	198.1	26.66
BB.F.S.	3.5	.224	9.7	.559	15.2	.512	273.7	26.88
Gr.F.S.	4.7	.314	9.9	.261	15.8	.641	306.3	20.69
BB.VIII.R. ..	3.8	.300	9.4	.499	11.2	.443	135.9	15.02
BB.VIII.S. ..	3.7	.337	8.8	.401	11.7	.337	123.5	7.88
Column ..	1	2	3	4	5	6	7	8

TABLE IV.

Variety, Stock, Method of Working.	Number of Grade II. Roots of 1st Order arising in				Number of Grade III. Roots of 1st Order arising in			
	Upper		Lower		Upper		Lower	
	Mean.	S.E.	Mean.	S.E.	Mean.	S.E.	Mean.	S.E.
II.R.Unworked ..	1.1	.28	4.5	.65	.1	.10	3.2	.53
VI.R.Unworked ..	7.2	1.27	7.3	1.34	1.5	.45	1.5	.30
II.II.R.	.9	.28	4.1	.59	.3	.17	4.0	.45
VI.VI.R.	3.8	.61	4.8	.99	1.6	.27	2.4	.34
BB.II.R.	1.0	.37	3.8	.87	.5	.22	3.0	.42
BB.VI.R.	4.4	1.29	6.5	1.06	2.6	.69	1.7	.30
Gr.II.R.	.8	.33	4.3	.62	.2	.13	5.0	.56
Gr.VI.R.	7.7	1.89	6.0	.91	3.2	.68	3.2	.42
BB.II.S.	1.9	.50	6.5	.79	1.2	.44	4.9	.62
BB.VI.S.	10.3	1.65	13.3	2.27	2.9	.59	2.9	.50
Gr.II.S.	1.6	.40	5.8	.68	.7	.30	5.1	.53
Gr.VI.S.	7.2	1.19	11.0	1.74	3.6	.85	4.8	.29
BB.F.R.	1.3	.52	5.8	1.18	.1	.10	9.0	.68
Gr.F.R.	1.0	.39	5.5	.96	.3	.15	8.4	.92
BB.F.S.	2.9	.57	9.4	1.14	2.1	.63	8.9	.67
Gr.F.S.	3.1	.64	7.6	1.09	2.1	.75	10.1	1.17
BB.VIII.R. ..	5.1	.98	3.9	.78	1.3	.52	3.7	.62
BB.VIII.S. ..	1.5	.43	9.8	2.21	1.5	.43	4.2	.77
Column	1	2	3	4	5	6	7	8

TABLE V.

Variety, Stock, Method of Working.	Percentage Total Root Weight in Upper.		Percentage Total Number Grade II. in Upper.		Percentage Total Number Grade III. in Upper.	
	Mean.	S.E.	Mean.	S.E.	Mean.	S.E.
II.R.Unworked	1.0	.58	19	4.6	2	2.0
VI.R.Unworked	40.4	10.02	45	7.8	41	10.1
II.II.R.	2.8	1.17	19	6.1	7	3.7
VI.VI.R.	41.4	9.13	46	7.1	40	6.7
BB.II.R.	9.2	3.80	20	6.0	13	6.0
BB.VI.R.	51.3	10.49	38	6.1	52	10.6
Gr.II.R.	5.3	3.32	14	6.1	3	1.7
Gr.VI.R.	45.9	9.95	53	7.4	46	8.2
BB.II.S.	10.2	4.13	23	5.9	15	4.8
BB.VI.S.	52.4	8.47	44	6.7	49	8.1
Gr.II.S.	1.9	.97	24	6.5	12	4.7
Gr.VI.S.	41.7	5.75	41	5.9	39	5.9
BB.F.R.	.6	.31	17	6.2	1	1.0
Gr.F.R.	4.3	2.78	18	6.6	4	2.6
BB.F.S.	27.3	6.08	25	4.9	16	3.8
Gr.F.S.	23.7	8.56	30	6.1	17	7.3
BB.VIII.R.	22.3	6.88	51	8.5	20	7.7
B.B.VIII.S.	16.3	6.58	17	5.7	24	5.0
Column	1	2	3	4	5	6

TABLE VI.

Variety, Stock, Method of Working.	Weight of Roots in gm.				Percentage Distribution between Grades.			
	Grade I.	Grade II.	Total I., II. & III.		Grade I.		Grades I. & II.	
	Mean.	Mean.	Mean.	S.E.	Mean.	S.E.	Mean.	S.E.
II.R. Unworked	3.06	9.93	46.75	7.45	6.8	.66	29.9	2.97
VI.R.Unworked	3.51	7.06	23.69	3.43	18.1	3.92	51.6	8.18
II.II.R.	2.55	8.68	40.74	3.45	6.4	.60	28.5	3.03
VI.VI.R.	2.91	6.95	35.27	1.90	8.3	.83	28.3	3.31
BB.II.R.	2.27	7.19	35.77	3.67	6.6	.64	26.6	2.43
BB.VI.R.	2.80	6.69	28.85	3.34	10.8	1.85	36.0	4.08
Gr.II.R.	2.49	9.44	44.65	5.66	5.7	.61	26.7	3.12
Gr.VI.R.	3.84	11.81	60.21	4.37	6.6	.62	26.9	2.73
BB.II.S.	2.73	9.20	40.98	3.31	6.8	.65	28.7	2.44
BB.VI.S.	4.44	8.25	36.85	5.31	13.8	1.78	40.5	1.80
Gr.II.S.	3.25	8.01	61.84	4.73	5.4	.34	18.2	1.53
Gr.VI.S.	4.36	11.69	65.45	5.73	7.1	.64	26.3	2.60
BB.F.R.	2.75	10.76	63.26	7.15	4.6	.70	22.8	3.15
Gr.F.R.	3.43	11.43	85.32	11.79	4.5	.52	19.1	2.47
BB.F.S.	2.92	12.96	50.84	6.62	6.5	.81	34.0	3.72
Gr.F.S.	4.54	13.63	98.35	5.01	4.7	.52	18.7	1.99
BB.VIII.R.	3.22	9.27	27.04	3.33	13.1	1.70	48.5	4.70
BB.VIII.S.	3.77	10.31	32.60	5.03	12.2	1.37	45.2	6.74
Column	1	2	3	4	5	6	7	8

Table VII.

Variety, Stock, Method of Working.	Weight of Grade I. Roots originating as Grade I., and arising from roots originating as Grade II. and Grade III. respectively.						Weight of Roots originating as Grade II.	
	As Grade I.		From Grade II.		From Grade III.			
	Mean.	S.E.	Mean.	S.E.	Mean.	S.E.	Mean.	S.E.
II.R.Unworked ..	.32	.046	.60	.096	2.14	.302	2.06	.344
VI.R.Unworked..	1.38	.251	1.35	.257	.78	.183	4.40	.689
II.II.R. ..	.35	.052	.45	.084	1.75	.272	2.08	.880
VI.VI.R... ..	.98	.220	.66	.079	1.27	.236	2.40	.111
BB.II.R. ..	.26	.054	.42	.103	1.59	.699	2.05	.594
BB.VI.R. ..	1.00	.174	.77	.115	1.03	.164	2.69	.516
Gr.II.R. ..	.27	.053	.36	.059	1.86	.397	1.63	.327
Gr.VI.R. ..	.98	.108	1.11	.196	1.75	.213	3.93	.522
BB.II.S.	.51	.064	.67	.112	1.55	.213	2.50	.386
BB.VI.S... ..	1.83	.222	1.36	.116	1.25	.194	4.66	.620
Gr.II.S. ..	.42	.090	.51	.110	2.31	.256	2.06	.379
Gr.VI.S. ..	1.07	.126	1.03	.116	2.26	.195	3.77	.465
BB.F.R.	.31	.054	.53	.099	1.89	.292	1.84	.377
Gr.F.R. ..	.28	.055	.53	.107	2.61	.122	2.08	.371
BB.F.S.	.73	.100	.98	.081	1.21	.145	3.88	.447
Gr.F.S.	.71	.120	.92	.129	2.91	.363	3.82	.585
BB.VIII.R. ..	.45	.109	.72	.112	2.05	.258	2.52	.438
BB.VIII.S. ..	.38	.083	.90	.141	2.48	.381	3.28	.798
Column ..	1	2	3	4	5	6	7	8

Table VIII.

Variety, Stock, Method of Working.	Number of Grade II. Roots arising from :—						Total Number Grade II. Roots.	
	Old Wood.		1st 20 cm. Grade III. Laterals.		2nd 20 cm. Grade III. Laterals.			
	Mean.	S.E.	Mean.	S.E.	Mean.	S.E.	Mean.	S.E.
II.R.Unworked ..	5.6	.78	5.0	.94	5.5	1.82	16.1	2.37
VI.R.Unworked..	14.5	2.22	.8	.06	2.3	.78	17.6	2.10
II.II.R. ..	5.0	.54	7.2	1.82	3.8	.61	16.0	2.00
VI.VI.R. ..	8.6	1.18	1.3	.09	2.3	.62	12.2	1.36
BB.II.R. ..	4.8	1.04	5.8	.98	4.0	.93	14.6	1.61
BB.VI.R. ..	10.9	1.87	1.7	.75	2.6	.56	15.2	1.93
Gr.II.R. ..	5.1	.67	7.3	.93	2.9	.57	15.3	1.35
Gr.VI.R. ..	13.7	2.20	2.0	.47	5.1	.94	20.8	2.47
BB.II.S.	8.4	.93	4.5	.95	2.5	.69	15.4	1.61
BB.VI.S... ..	23.6	3.08	.2	.13	.9	.31	24.7	2.98
Gr.II.S. ..	7.4	.78	6.1	.94	3.0	.97	16.5	1.38
Gr.VI.S. ..	18.2	2.01	2.0	.58	4.0	1.12	24.2	1.93
BB.F.R.	7.1	1.49	4.5	1.18	2.2	.65	13.8	2.12
Gr.F.R. ..	6.5	.89	4.6	1.23	2.9	1.09	14.0	1.90
BB.F.S.	12.3	.97	2.0	.42	1.8	.42	16.1	.88
Gr.F.S.	10.7	1.08	6.3	1.80	4.6	.96	21.6	2.61
BB.VIII.R. ..	9.0	1.36	7.9	1.76	2.0	.70	18.9	2.40
BB.VIII.S. ..	11.3	2.03	9.0	1.35	2.3	1.22	14.5	3.68
Column ..	1	2	3	4	5	6	7	8

Respect in which the two Members of a Pair Differ.		Pairs of Batches compared. e.g. BB.II. (**R.** & **S.**) denotes the pair of batches, Beauty of Bath on Stock No. II. (grafted on Piece Roots (**R.**) and Stem-grafted on Layers (**S.**) respectively.	Tree Characters.				Stem		
							Wood* Growth.		
			Total Tree Weight.	" Carcase " Weight, i.e., Tree less Roots.	Total Root Weight.	Root Weight as percentage Total Tree Weight.	Maiden (1928).	2nd Year (1929).	Total.
Section A.	**Method of Working.** Piece Root (**R**). and Stem-worked Layers (**S**.)	BB.II.(**R. & S.**)	—	—	—	**S.**	—	—	—
		BB.VI.(**R. & S.**) ..	—	—	—	—	**S.**	**R.**	—
		Gr.II.(**R. & S.**)	—	—	**S.**	**S.**	—	—	—
		Gr.VI.(**R. & S.**)	—	—	—	**S.**	—	—	—
Section B.	**Scion.** Beauty of Bath (**BB**.) and Grenadier (**Gr.**)	(**BB. & Gr.**)II.R. ..	—	—	—	**Gr.**	—	—	—
		(**BB. & Gr.**)II.S. ..	—	—	**Gr.**	**Gr.**	—	—	—
		(**BB. & Gr.**)VI.R. ..	—	—	**Gr.**	**Gr.**	**Gr.**	**BB.**	—
		(**BB. & Gr.**)VI.S. ..	—	—	**Gr.**	**Gr.**	—	—	—
Section C.	**Stock.** No. II. (**II.**) and No. VI. (**VI.**)	BB(**II. & VI.**)R. ..	—	—	—	—	—	—	—
		BB(**II. & VI.**)S.	—	—	—	—	—	—	—
		Gr.(**II. & VI.**)R. ..	—	—	**VI.**	**VI.**	**VI.**	—	**VI.**
		Gr.(**II. & VI.**)S.	—	—	—	—	**VI.**	—	—
Cross Reference to Tables of Mean Values.		Table	I.	III.	VI.	I.	II.	II.	II.
		Column	5	7	3	7	11	3	5

For explanation of Charts, see Text, Section D.2., page 266.

* 1st Order Roots—those borne

T I.

cters.					Root Characters.									
Diameters.			Total Fibre as percentage Root Weight.		Percentage in Upper Half.			Distribution of Root Branches.						
5 cm. from Tip.	Middle.	5 cm. from Base.	Grade I. 1mm. or less.	Grades I. & II. 3mm. or less.	Of No. of 1st Order. Grade II. Roots.	Of No. of 1st Order Grade III. Roots.	Of Total Root Weight.	1st Order Fibre as percentage Root Weight.		Number of 1st and 2nd Order Grade II. and III.* **OW.** 1st Order (Old Wood). **AB.** 2nd Order (1st 20 cm.) **BC.** 2nd Order (2nd 20 cm.) from 1st Order Grade III.				
								Grade I.	Grade II.	Grade II.			Grade III.	
										OW.	**AB.**	**BC.**	**OW.**	**AB.**
—	—	—	—	—	—	—	—	—	—	**S.**	—	—	**S.**	**R.**
R.	—	—	—	—	—	—	—	—	—	**S.**	—	**R.**	**S.**	—
—	—	—	—	**R.**	—	—	—	—	—	**S.**	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gr.	—	**BB.**	—	—	—	—	—	—	—	—	—	—	**Gr.**	—
Gr.	—	—	—	**BB.**	—	—	—	—	**BB.**	—	—	—	—	—
Gr.	—	—	**BB.**	—	—	—	—	**BB.**	—	—	—	**Gr.**	**Gr.**	**Gr.**
Gr.	—	—	**BB.**	**BB.**	—	—	—	**BB.**	**BB.**	—	**Gr.**	**Gr.**	**Gr.**	—
—	—	—	**VI.**	—	—	**VI.**	**VI.**	**YI.**	—	**VI.**	**II.**	—	—	**II.**
II.	—	—	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	**II.**	**II.**	—	—
—	—	—	—	—	**VI.**	**VI.**	**VI.**	**VI.**	—	**VI.**	**II.**	—	—	—
—	—	—	**VI.**	**VI.**	—	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	**II.**	—	**VI.**	—
III.	III.	III.	VI.	VI.	V.	V.	V.	IX.	IX.	VIII.	VIII.	VIII.	IX.	IX.
1	3	5	5	7	3	5	1	5	5	1	3	5	1	1

t on old wood of stem-layer or piece root. 2nd Order Roots—those rising from 1st Order Roots.

CHART

Respect in which the two Members of a Pair Differ.		Pairs of Batches Compared. For explanation of Notation see Chart I.	Tree Characters.				Stem Characters.				
							Wood Growth.				
			Total Tree Weight.	" Carcase " Weight. i.e., Tree less Roots.	Total Root Weight.	Root Weight. as percentage Total Tree Weight	Maiden (1928).	2nd Year (1929).	Total.	Maiden as Percentage of Total.	
Section D.	**Method.** Unworked and Worked.	II.(**unw. & w.**) ..	—	—	—	**unw.**	—	—	—	—	
		VI.(**unw. & w.**)	**w.**	**w.**	**w.**	—	**w.**	**unw.**	—	**w.**	
Section E.	**Stock & Scion.** No. II. & VI.	(**II. & VI.**) unworked ..	**II.**	**II.**	**II.**	—	**II.**	—	**II.**	**II.**	
		(**II. & VI.** worked ..	**II.**	**II.**	—	—	—	**II.**	**II.**	**VI.**	
Section F.	**Scion.** No. II. or VI. and Beauty of Bath or Grenadier.	(**II. & BB.**)II.R. ..	—	—	—	**II.**	—	—	—	—	
		(**II. & GR.**)II.R. ..	—	—	—	**Gr.**	—	—	**II.**	—	
		(**VI. & BB.**)VI.R. ..	—	—	—	—	—	**BB.**	**BB.**	**VI.**	
		(**VI. & Gr.**)VI.R. ..	**Gr.**	—	**Gr.**	—	**Gr.**	**Gr.**	**Gr.**	—	
Section G.	**Method of Working.**	BB.VIII.(**R. & S.**) ..	—	—	—	—	—	—	—	—	
Section H.	**Stock.** No. VIII. and No. II. or VI.	BB.(**II. & VIII.**)R. ..	**II.**	**II.**	—	—	—	—	—	—	
		BB.(**II. & VIII**)S. ..	—	—	—	—	—	—	—	—	
		BB.(**VI. & VIII.**)R. ..	—	—	—	—	—	—	—	—	
		BB.(**VI. & VIII.**)S. ..	—	—	—	—	**VI.**	—	—	—	
Cross Reference to Tables		Table	I.	III.	VI.	I.	II.	II.	II.	II.	I
of Mean Values.		Column	5	7	3	7	1	3	5	7	

For explanation of Charts see Text, Section D.2., page 266.

* 1st Order Roots—those borne direct o

ameters.		Root Characters.											
		Total Fibre as percentage Root Weight.		Percentage in Upper Half.			Distribution of Root Branches.						
							1st Order Fibre as percentage Root Weight.		Number of 1st and 2nd Order Grade II. and III.* **OW.** 1st Order (Old Wood) **AB.** 2nd Order (1st 20 cm.) **BC.** 2nd Order (2nd 20 cm.) from 1st Order Grade III.				
									Grade II.			Grade III.	
Middle.	5 cm. from Base.	Grade I. 1 mm. or less.	Grades I. & II. 3mm. or less.	Of No. of 1st Order Grade II. Roots.	Of No. of 1st Order Grade III. Roots.	Of Total Root Weight.	Grade I.	Grade II.	**OW.**	**AB.**	**BC.**	**OW.**	**BC.**
—	—	—	—	—	—	—	—	—	—	—	—	—	—
w.	**w.**	—	**unw.**	—	—	—	**unw.**	**unw.**	**unw.**	—	—	—	—
VI.		**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	**II.**	—	—	**II.**
—	—	—	—	**VI.**	**VI.**	**VI.**	**VI.**	—	**VI.**	**II.**	—	—	**II.**
—	**BB.**	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
VI.	—	—	—	—	—	—	—	—	—	—	—	—	—
VI.	—	—	—	—	—	—	—	—	—	—	**Gr.**	**Gr.**	—
—	—	—	—	**R.**	—	—	—	—	—	—	—	—	—
—	**II.**	**VIII.**	**VIII.**	**VIII.**	—	—	—	—	**VIII.**	—	—	—	—
—	—	**VIII.**	**VIII.**	—	—	**VIII**	—	—	—	**VIII.**	—	—	—
—	—	—	—	—	**VI.**	**VI.**	—	—	—	**VIII.**	—	—	—
—	—	—	—	**VI.**	**VI.**	**VI.**	—	—	**VI.**	**VIII.**	**VIII.**	—	
III.	III.	VI.	VI.	V.	V.	V.	IX.	IX.	VIII.	VIII.	VIII.	IX.	IX.
3	5	5	7	3	5	1	5	7	1	3	5	1	3

wood of stem-layer or piece root.

2nd Order Roots—those rising from 1st Order Roots.

CHAR

Respect in which the two Members of a pair Differ.			Pairs of Batches Compared. For explanation of Notation see Chart I.	Tree Characters.				Stem Ch			
								Wood Growth.			
				Total Tree Weight.	" Carcase " Weight. i.e. Tree less Roots,	Total Root Weight.	Root Weight as percentage Total Tree Weight.	Maiden (1928).	2nd year (1929)	Total.	Maiden as percentage
Section J.	**Method.** High (**S.**) and Low (**R.**).		BB.F.(**S. & R.**) ..	—	—	—	**R.**	—	—	—	—
			Gr.F.(**S. & R.**)	**S.**	**S.**	—	**R.**	**S.**	—	—	—
Section K.	**Scion.** Beauty of Bath and Grenadier.		(**BB. & Gr.**)F.R. ..	—	—	—	**Gr.**	—	—	**BB.**	—
			(**BB. & Gr.**)F.S.	—	—	**Gr.**	**Gr.**	—	—	—	**Gr.**
Section L.	**Stock**	No. II and Free Seedling.	BB.(**II. & F.**)R.	—	—	**F.**	**F.**	**F.**	—	**F.**	**F**
			BB.(**II. & F.**)S.	**F.**	**F.**	—	**II.**	**F.**	—	**F.**	**F**
			Gr.(**II. & F.**)R.	—	—	**F.**	**F.**	—	—	—	—
			Gr.(**II. & F.**)S.	**F.**	**F.**	**F.**	—	**F.**	—	**F.**	**F.**
		No. VI. and Free Seedling.	BB.(**VI. & F.**)R. ..	**F.**	**F.**	**F.**	**F.**	**F.**	—	—	**F.**
			BB(**VI. & F.**)S.	**F.**	**F.**	—	—	—	—	—	—
			Gr.(**VI. & F.**)R.	—	—	—	**F.**	—	—	—	—
			Gr.(**VI. & F.**)S.	**F.**	**F.**	**F.**	**VI.**	**F.**	—	**F.**	**F.**
		No. VII. and Free Seedling.	BB.(**VIII. & F.**)R. ..	**F.**	**F.**	**F.**	**F.**	**F.**	—	**F.**	**F.**
			BB (**VIII. & F.**)S. ..	**F.**	**F.**	—	**VIII.**	**F.**	—	**F.**	—
Cross Reference to Tables			Table	I.	III.	VI.	I.	II.	II.	II.	II.
of Mean Values.			Column ..	5	7	3	7	1	3	5	7

For explanation of Charts, see Text, Section D.2., page 266. *1st Order Roots—those borne direct on

I.

ers.			Root Characters.											
Diameters.			Total Fibre as percentage Root Weight.		Percentage in Upper Half.			Distribution of Root Branches.						
								1st Order Fibre as percentage Root Weight.		Number of 1st and 2nd Order Grade II. and III.* **OW** 1st Order (Old Wood) **AB.** 2nd Order (1st 20 cm.) **BC.** 2nd Order (2nd 20 cm.) from 1st Order Grade III.				
										Grade II.			Grade III.	
5 cm from tip	Middle.	5 cm. from Base.	Grade I. 1 mm. or less.	Grades I. & II. 3 mm. or less.	Of No. of 1st Order Grade II. Roots.	Of No. of 1st Order Grade III. Roots.	Of Total Root Weight.	Grade I.	Grade II.	**OW.**	**AB.**	**BC.**	**OW.**	**AB.**
—	—	—	—	**S.**	—	**S.**	**S.**	**S.**	**S**	**S.**	—	—	—	—
—	—	**S.**	—	—	—	—	**S.**	**S.**	—	**S.**	—	—	**S.**	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
r.	—	—	—	**BB.**	—	—	—	**BB.**	**BB.**	—	**Gr.**	**Gr.**	—	—
I.	—	—	**II.**	—	—	—	**II.**	—	—	—	—	—	**F.**	**II.**
–	—	—	—	—	—	—	**F.**	—	—	**F.**	**II.**	—	**F.**	—
I.	—	—	—	—	—	—	—	**II.**	—	—	—	—	**F.**	—
–	—	**F.**	—	—	—	—	**F.**	—	—	**F.**	—	—	**F.**	—
–	—	—	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	—	—	—	**F.**	**F.**
–	—	—	**VI.**	—	**VI.**	**VI.**	**VI.**	**VI.**	—	**VI.**	**F.**	—	**F.**	—
I.	—	—	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	**VI.**	—	—	**F.**	—
–	—	**F.**	**VI.**	**VI.**	—	**VI.**	—	**VI.**	—	**VI.**	**F.**	—	**F.**	**F.**
–	—	**F.**	**VIII.**	**VIII.**	**VIII.**	**VIII.**	**VIII.**	**VIII.**	**VIII.**	—	**VIII.**	—	**F.**	—
–	—	**F.**	**VIII.**	—	—	—	—	—	—	—	**VIII.**	—	—	—
I.	III.	III.	VI.	VI.	V.	V.	V.	IX.	IX.	VIII.	VIII.	VIII.	IX.	IX.
	3	5	5	7	3	5	1	5	7	1	3	5	1	3

wood of stem-layer or piece roots. 2nd Order Roots—those rising from 1st Order Roots.

THE INCIDENCE AND CONTROL OF APPLE SCAB AND APPLE MILDEW AT EAST MALLING.

(Continued.)

By M. H. MOORE.
East Malling Research Station.

INTRODUCTION.

The details concerning this investigation are explained fully in the earlier part of the paper (10), which deals only with Apple Scab. The present contribution describes the results obtained in the control of Apple Mildew, and, in the section on Spray Injury, discusses the safety or otherwise of the different spray fluids used in the main experiments. The results obtained in the control of the two diseases mentioned above are in certain cases nullified by severe spray damage. This should be borne in mind when the respective merits of any of the sprays are being compared.

PART II. APPLE MILDEW.

I. THE EFFECT OF SPRAYING AND DUSTING.

Records of infection of Cox's Orange Pippin by Apple Mildew were made concurrently with those of Scab on the same trees, so that the description of the spraying experiments already given in Part I of this paper applies here also.

Counts of the number of mildewed shoots were made after the trees had uniformly been winter pruned. They were made both on the prunings and on the trees in the following spring (for the effect of spraying is cumulative with Mildew as well as with Scab). The figure for each tree was then expressed as a percentage of the number of current year's shoots. Thus :

Total infections, 30 ; current year's shoots, 210 ;

$$\text{Mildew} = \frac{30 \times 100}{210}$$

$$= 14 \text{ per cent. (in round numbers).}$$

The following table contains the average figures for the three years during which the observations were carried out.

TABLE I.*

Control of Apple Mildew on Young Shoots.

Variety—Cox's Orange Pippin.

Spray Treatment.	Stock.	Average % Mildew.		
		1926	1927	1928
Expt. I :				
B.M. +A. 1 pre-blossom	I	42	69	33
L.-S. +A. ,, ...		33	54	33
Control A. ,, ...		47	76	45
B.M. +A. ,, ...	II	31	64	31
L.-S. +A. ,, ...		24	63	33
Control A. ,, ...		31	64	38
Expt. IV :				
B.M. +A. 2 post-blossom	XIII	16	40	27
L.-S. +A. ,, ...		13	25	16
Control A. ,, ...		25	43	30
Expt. II :				
B.M. +A. 1 pre- and 2 post-blossom	III	11	14	21
L.-S. +A. ,, ,, ..		9	5	14
Control A. ,, ,, ..		19	22	35
Expt. III :				
B.M. 1 pre- and 2 post-blossom	IV	20	23	14
L.-S. ,, ,, ..		6	17	3
Control Nil ,, ,, ..		16	38	15
Expt. V :				
L.-S. +G. 2 post-blossom	X	25	29	24
C.S. +G. ,, ...		24	41	31
Control G. ,, ...		35	64	33

Examination of the figures shows that in Expt. I, slight reduction of infection by lime-sulphur is indicated. Bordeaux mixture has given little control, especially on No. II rootstock, although in 1928 it was as good as lime-sulphur.

In Expt. IV, lime-sulphur reduced infection by about one half and proved better than when applied as a single pre-blossom spray. Bordeaux mixture has had practically no effect.

In Expt. II and III, both fungicides are seen to have reduced infection when applied three times, lime-sulphur giving a consistently better result than Bordeaux mixture. Slight control by the latter spray is probably due to the inclusion of a pre-blossom application, for this alone reduced infection slightly (Expt. I) while two post-blossom applications did not (Expt. IV).

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* It was stated in Part I that the results for trees on *all* rootstocks are not given in these tables; those not included, however, conform, in general, to those tabulated.

Comparison of Expt. II and III, which are identical except that lead arsenate was omitted in the latter, shows that there is little evidence of decrease in the fungicidal activity of lime-sulphur against Mildew when arsenate is included (the basis of comparison being the amount of infection on the control trees, thus nullifying, largely, the possible effect of rootstock). The possibility of this was suggested by Grubb (8).

In Expt. V, both colloidal sulphur and very weak lime-sulphur (1-150) are seen to have reduced infection slightly, the effect of the latter, with gelatine, comparing very favourably with that of the stronger post-blossom lime-sulphur (1-100) in Expt. IV.

The results thus show that three applications of lime-sulphur gave the best results, although entirely satisfactory control was not attained.*

The apparent increase in the amount of infection since 1926 is explained by the fact that mildew infections remaining on the tree after pruning were not included in that year, while they were taken into account in the following two years.

Trees of the variety Stirling Castle are interplanted in alternate rows with the Cox's Orange Pippin, and, like the latter, they are also worked on various known rootstocks. On these trees the following sprays were used:—Lime-sulphur, ammonium polysulphide, liver of sulphur and colloidal sulphur, all with the addition of an efficient spreader. There was, however, so little Mildew infection on these trees during the three years that close examination of the figures obtained would be fruitless. One point stands out, namely, that where control has occurred, lime-sulphur was the most efficient of the four sprays. This gave the best result when applied three times, one pre- (1-30) and two post-blossom (1-100). This result is similar to that obtained with Cox's Orange Pippin.

Two post-blossom applications of lime-sulphur at 1-100 and 1-150 respectively reduced infection somewhat, but the former afforded no better control than the latter (see under Cox's Orange Pippin). Liver of sulphur (0.3 per cent.), ammonium polysulphide (1-200) and colloidal sulphur (0.4 per cent.) proved of little value as post-blossom applications.

A plot of 100 trees of the variety Belle de Boskoop, all of the same age and worked on No. IX rootstock, was available for a spraying experiment in 1928, and a comparative trial of nine different specifics was made, with the necessary controls.

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* A large proportion of the infections recorded on lime-sulphur-sprayed trees were found at the extreme tips of young shoots, and had caused no appreciable damage. For the purpose of obtaining comparable data, however, such infections, many of which would pass unnoticed in commercial practice, were included in these records. The measure of control given by three applications of lime-sulphur can therefore be regarded as satisfactory from a commercial point of view, although it must be borne in mind that such control was obtained by spraying in conjunction with thorough winter pruning.

Two post-blossom applications of each fungicide were given, the first at petal fall, the second about three weeks later. Sprays were applied with a hand-pumped knapsack machine, and dusts with a hand-operated blower. Hessian screens were used to protect other trees in the experiment from spray or dust "drift."

The experiment was repeated in 1929. The number of Mildew infections on each tree was recorded in each year just before leaf fall, and the totals for every ten trees in each differently treated group are given in Table II. The total number of fruit and the amount of russeting on them (estimated by the "category" method previously described) are also given for 1929. The crop in 1928 was too small to permit the obtaining of such data.

TABLE II.

Control of Apple Mildew on Belle de Boskoop.

	Total No. of infections per ten trees.		Total No. fruit picked.	Average "russeting equivalent."
Treatment.	1928	1929	1929	1929
1. Lime-sulphur (1-100)	18	13	164	4·7
2. Colloidal sulphur (0.4%)	35	21	351	4·2
3. Ammonium polysulphide (1-200) ..	22	23	393	4·7
4. Liver of sulphur (0.3%)	26	9	430	5·1
5. Proprietary sulphur spray	28	11	235	5·5
6. Soda-soap solution (20-10-100) ..	12	1	75	5·9
7. Proprietary white oil emulsion ..	22	18	145	3·0
8. Flowers of sulphur	35	21	347	5·0
9. Proprietary dusting sulphur ..	17	14	459	4·1
10. Untreated controls	27	15	475	5·4

Before the materials were applied in 1928 all existing infections of mildew were removed so that the trees were uniform at the outset. In 1929, however, existing infections were not removed, in order that the cumulative effect of the fungicides might be shown in the second year's results. In 1928, gelatine spreader, at the rate of ½ lb. per 100 gallons, was used with the first four sprays only. In 1929, however, the same spreader, at 1 lb. per 100 gallons, was used not only with these four sprays but also with the proprietary sulphur spray and the white oil emulsion. The improvement in the delivery of and "wetting" by the last-named was very noticeable. The control trees were sprayed with gelatine solution in 1929.

It will be observed from the figures that, although in neither year was this variety heavily infected, yet there was, on the whole, much more infection in 1928 than in 1929. Soda-soap solution (tested because of its known efficacy against American Gooseberry Mildew), the proprietary dusting sulphur, and lime-sulphur, showed the best results in 1928, the first having been the most effective.

As compared with the untreated controls none of the other specifics reduced infection appreciably. In 1929 the efficiency of soda-soap solution again stood out, while liver of sulphur and the proprietary sulphur spray gave better results than in 1928. Possibly the inclusion of gelatine in 1929 assisted the last-named, but the slight infection on all trees in 1929 suggests that the seasonal factor was the most important one leading to the discrepancy in results shown by the same sets of trees in the two years.

Although soda-soap solution was the only fungicide that reduced infection consistently it was also the only one in both seasons that produced scorching of the young tips of the current year's growth, causing them to turn bright red.

From the number of fruits picked in 1929 it would appear that some of the treatments caused fruit drop. This was especially marked with soda-soap solution, white oil emulsion, lime-sulphur and the proprietary sulphur spray, all four of the results being significant, in spite of high individual variation. Flowers of sulphur, colloidal sulphur and ammonium polysulphide also appear to have reduced the crop slightly. The sulphur dust caused leaf drop.

The fruits from the soda-soap-sprayed trees showed most russeting, while those from the trees sprayed with white oil emulsion showed the least, much less, indeed, than those from the untreated controls. The russeting was closely associated with a fungus believed to be *Coniothecium chomatosporum*, and described by van der Bijl (2) and by Cunningham (3) as the cause of apple russeting in South Africa and New Zealand respectively.*

Statistical analysis of the results shows that the fruits from trees sprayed with white oil emulsion were significantly less russeted than those treated with the other preparations except the proprietary dusting sulphur and colloidal sulphur, while the fruits from trees treated with these two specifics were significantly less blemished than those from the control trees.

The above results are those for one year only (1929), hence variable seasonal conditions do not enter into them. There is fairly clear evidence, however, that soda-soap solution, white oil emulsion, lime-sulphur and the proprietary sulphur spray were not safe on this variety at the strengths used.

II. THE EFFECT OF ROOTSTOCK.

As with Scab, the spraying records on Cox's Orange Pippin also show the influence of rootstock on the degree of Mildew infection. The figures in Table III were obtained from the *control* trees only, and represent the percentage number of infected shoots.

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* Studies of this fungus have not yet been made at East Malling and whether it is a primary cause of russeting or not is as yet scarcely certain.

TABLE III.

Influence of Rootstock on the Incidence of Apple Mildew.

Variety—Cox's Orange Pippin.

Rootstock.	% Mildew in 1926.	% Mildew in 1927.	% Mildew in 1928.	
I	47	76	45	Inducing susceptibility.
II	31	64	38	
X	35	64	33	
VI	34	57	29	Intermediate.
V	21	57	33	
IX	24	49	33	
XIII	25	43	30	
III	19	22	35	Inducing resistance.
XV	19	35	22	
IV	16	38	15	
XVI	18	15	29	

Apart from occasional seasonal variations, the results for the three years are fairly consistent and trees on No. I stock were outstandingly susceptible in all three seasons. The stocks may tentatively be classified as in the above table. By comparison with Table V already given in the Part I of this paper it will be observed that stock No. I induces susceptibility to both Scab and Mildew, while stocks No. XV and III induce resistance to both diseases. Experience of No. III in the nursery, unworked, however, has shown that it suffers badly from both Scab and Mildew.

Exceptions to the above general statement were afforded in 1927 by trees on No. XV and on No. IV (moderately infected) and, in 1928, by trees on No. X, on No. III and on No. XVI (moderately infected), the term being a relative one for a particular year. Further reference to Mildew in connection with rootstock will be found in the following section.

III. THE EFFECT OF MANURING.

Records of the numbers of mildew infections were obtained by members of the Pomology Staff in 1928 on Bramley's Seedling on the manured and the unmanured plots described in the Section dealing with Scab. The results are assembled in Table IV.

Unfortunately, the only available means of standardizing the size of the trees for interpreting the data on Mildew infection is by comparing the girths of the main stems. These, while positively correlated with some measurements of vigour (e.g., new shoot growth) do not always bear a similar relationship to the same expressions of vigour when conditions (e.g., rootstock) are changed.

TABLE IV.

*Records of Mildew Counts on Manured and Unmanured Plots.**

Variety—Bramley's Seedling. 1928.

	Manured Plot.			Unmanured Plot.		
Rootstock No.	No. Trees.	Average No. infections per tree.	Girth, 1928, in mm.	No. Trees.	Average No. infections per tree.	Girth, 1928, in mm.
VI	8	71	374	16	83	369
III	8	98	384	15	65	348
V	8	85	367	16	73	347
II	8	80	370	16	83	357
IV	8	84	383	16	55	362
VII	8	47	342	14	32	332
X	8	108	273	16	62	307
I	8	92	372	16	108	369

The most outstanding difference is afforded by trees on No. X rootstock. They are bigger on the unmanured than on the manured plot, while there was much more Mildew on the latter trees than on the former. This may be due to the unsuitability of No. X as a rootstock for Bramley's Seedling. In general, comparable trees are larger on the manured plot, and were more heavily infected by Mildew than those on the unmanured plot.

Thus, from the data available, there is no significant difference between the amount of Mildew on unmanured and manured trees, apart from that which can probably be accounted for by the difference in the size of the trees, while, of the rootstocks, the only one indicating a possible influence is No. I. Trees on this stock on the unmanured plot were more heavily infected, for their size, than were those on other stocks. The same applies to trees on this stock on the manured plot, though to a lesser extent. It will be recalled that Cox's Orange Pippin, on this rootstock, was also more heavily infected than it was when worked on other rootstocks.

Any other apparent differences in the figures (such as the beneficial effect of manuring trees on No. VI, on No. II and on No. I stocks) are not significant, on account of the wide individual variations in figures providing the final average.

IV. SUMMARY AND CONCLUSIONS IN REGARD TO APPLE MILDEW.

1. Spraying experiments on Cox's Orange Pippin and Stirling Castle showed that lime-sulphur applied three times, first, in the " pink bud " stage, at 1-30, second, at petal-fall, at 1-100, and third, three weeks later, at the same strength,

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* The writer is indebted to the Pomology Staff at East Malling for the use of these figures.

gave the best control of this disease. Gelatine was used as a spreader on Stirling Castle. Bordeaux mixture proved of little value in checking infection on Cox, while sulphur sprays are not safe to use on Stirling Castle. Both colloidal sulphur and lime-sulphur (1-150), each with gelatine as spreader, as post-blossom applications, reduced infection slightly, lime-sulphur at the strength used comparing very favourably with the same at 1-100 used with arsenate of lead and no spreader.

2. Preliminary spraying and dusting experiments with Belle de Boskoop showed very good control of Mildew by two post-blossom applications of soda-soap solution (20-10-100), which, however, caused so much fruit drop that it is not safe to use at that strength on this variety. The other specifics tested showed little consistent promise, although the amount of infection during the two seasons was too slight to reveal significant diff rences in most cases. A proprietary white oil emulsion, lime-sulphur, and a proprietary sulphur spray all significantly reduced the crop, in the one year, while there was significantly less fruit russeting on trees sprayed with white oil emulsion than on other trees, except those treated with the proprietary dusting sulphur and colloidal sulphur.

3. The results show that the rootstock upon which the scion variety is "worked" has an influence on the degree of infection by Mildew, stock No. I consistently inducing susceptibility. From the data available, manurial treatments had no significant effect on the degree of infection on Bramley's Seedling in 1928.

PART III. SPRAY INJURY.

I. THE RELATION OF SPRAYS TO SPRAY INJURY.

Reference has been made already to injury on Cox's Orange Pippin by Bordeaux mixture (10) and on Belle de Boskoop by several other preparations. It is proposed to deal here more fully with the various types of injury observed during the Scab-prevention trials with Cox's Orange Pippin and Stirling Castle. The effect of the sprays in controlling Scab and Mildew must of course be taken in conjunction with any spray injury caused, if the true practical value of the different fungicides is to be appraised. The chief injuries fall under the headings leaf drop, leaf scorch, fruit drop and fruit russeting. These will be discussed in turn for Cox's Orange Pippin and Stirling Castle.

I. COX'S ORANGE PIPPIN.

(a) *Leaf Drop.*—The collection of the leaves prematurely falling from sprayed and unsprayed trees was made by means of troughs of hessian suitably supported around representative trees, as described fully by Frampton (6).

In 1929 this method was not found convenient as the trees had become too big for the troughs originally made for them. In this year, therefore, the number of leaves on the ground underneath each tree were counted ; and, although this method was not so accurate, it proved adequate to show the main differences.

The photographs reproduced in Fig. I and II present a general view of the spraying trial plot, with the hessian troughs in position, and a nearer view of one of the troughs. These troughs were erected immediately after the first post-blossom application, and they were examined every two or three days afterwards, when the leaves were removed and counted. The results are assembled in Table V.

TABLE V.

Leaf Drop on Cox's Orange Pippin.

Spray treatment.	Average total leaf drop per tree at end of season.			
	Stock.	1927	1928	1929
B.M. +A. 1 pre-blossom	I	941	461	11
L.-S. +A. ,,		404	477	5
Control A. ,,		474	627	6
B.M. +A. 2 post-blossom	V	639	845	20
L.-S. +A. ,,		688	1083	9
Control A. ,,		641	661	7
B.M. +A. 1 pre- and 2 post-blossom	III	352	380	58
L.-S. +A. ,,		369	995	8
Control A. ,,		577	1051	18
L.-S. (1-150) +G. 2 post-blossom	X	565	870	6
C.S. +G. ,,		301	615	10
Control G. ,,		546	888	7

Minor fluctuations in the figures are due to individual tree variation, chiefly as a result of differences in the size of trees on the same rootstock. The average is thus considerably affected by the lack of uniformity shown by certain trees in the three seasons.

The figures for 1927 and 1928 are the average numbers of all the dropped leaves per tree, but those for 1929 were obtained from records made on a certain portion of ground under each tree. A sector on the N.W. side of the tree was chosen in each case. Though obtained in this somewhat crude manner, they show that Bordeaux mixture (8-12-100, made with hydrated lime) caused leaf drop at whatever period it was applied in that year.

More leaves dropped from the arsenate-sprayed control trees in many cases than from those sprayed with a fungicide, probably because of the lack of control of Scab on the former. There is no evidence that spraying with lead arsenate has caused leaf drop, for gelatine-sprayed controls and unsprayed trees showed similar amounts. There is a strong suggestion that lime-sulphur applied post-blossom to trees on No. V rootstock caused leaf drop in 1928 but not in the other two years.

Bordeaux mixture made with quick lime caused some leaf drop in 1928 when applied post-blossom only, to trees on No. V stock, although where a pre-blossom spray was also given, as on trees on No. III stock, there was no evidence of leaf drop. This suggests that the pre-blossom application may have had the effect of preventing " Bordeaux shock " from occurring after blossoming in that year, a point referred to by Frampton (6) in 1926. There was no indication of this effect in the following year, when severe injury resulted from all applications of hydrated-lime Bordeaux (see Fig. III). It should be added that colloidal sulphur caused no leaf fall in these experiments.

(b) *Leaf Scorch.*—This was estimated just as described for Scab on the leaves (see p. 236, Part I) (10). Cox's Orange Pippin is liable to show small reddish, circular spots on the earlier formed leaves (the cause of which is not known with certainty) especially in a dry summer, and it was found very difficult to distinguish between these spots and scorch due solely to spraying. All scorch therefore, was estimated, and the difference between the amount on sprayed and that on unsprayed trees can be regarded as directly resulting from the spray treatment.

The accompanying Table VI shows the results obtained during the three years. Each figure is the average of " categories " into which trees on the same rootstock, having the same spray treatment, were placed as a result of inspection.

In 1927, pre-blossom lime-sulphur caused slight marginal leaf scorch. This was insignificant, and the effect was not noticeable when the trees came into full leaf. Neither Bordeaux mixture nor lead arsenate caused any injury at this time. Bordeaux mixture, post-blossom, produced fairly severe scorching, which was not prevented by a preceding pre-blossom application. The injury remained visible until late in the season. Lime-sulphur and colloidal sulphur did not cause similar damage when applied post-blossom.

In 1928, both lime-sulphur and Bordeaux mixture, pre-blossom, caused slight leaf scorch, but, as before, the effect was visible only temporarily. Post-blossom applications of both fungicides also resulted in leaf scorch on trees on No. V stock, while there is evidence by comparing trees on stock No. V with those on stock No. III, that a pre-blossom spray prevented to some extent post-blossom " Bordeaux shock " and " lime-sulphur shock." This was indicated in the same year by the leaf drop data (see p. 291). On the other hand, it is possible that trees on No. V rootstock are more susceptible to leaf scorch than those on No. III. The amount of leaf scorch on the respective control trees on

TABLE VI.

Leaf Scorch on Cox's Orange Pippin.

Spray Treatment.	Stock	1927			1928			1929		
		After Pre-	1st Post-	2nd Post-	Pre-	1st Post-	2nd Post-	Pre-	1st Post-	2nd Post-
B.M. +A. 1 pre-blossom	II	0.0	0.8	0.4	1.0	1.6	1.4	—	2.2	1.2
L.-S. +A. 1 pre-blossom		1.0	0.6	0.8	0.8	1.6	1.6	—	1.2	1.0
Control A. 1 pre-blossom		0.0	0.5	0.5	0.0	1.7	1.5	—	1.7	1.3
B.M. +A. 2 post-blossom	V	0.0	2.6	2.0	0.0	3.2	2.2	—	3.2	4.0
L.-S. +A. 2 post-blossom		0.0	0.8	0.2	0.0	2.0	2.0	—	1.4	1.6
Control A. 2 post-blossom		0.0	0.5	0.5	0.0	1.5	1.3	—	1.3	1.7
B.M. +A. 1 pre- and 2 post-blossom ..	III	0.0	3.0	1.8	1.2	2.8	2.4	—	3.4	4.0
L.-S. +A. 1 pre- and 2 post-blossom ..		1.0	1.2	0.6	1.0	1.2	1.6	—	1.0	1.6
Control A. 1 pre- and 2 post-blossom ..		0.0	1.0	0.8	0.0	2.0	2.0	—	1.5	2.3
L.-S. (1-150) +G. 2 post-blossom ..	VI	0.0	0.4	0.4	0.0	1.6	1.8	—	1.0	1.2
C.S. +G. 2 post-blossom		0.0	0.8	0.2	0.0	2.0	1.8	—	1.2	1.2
Control G. 2 post-blossom		0.0	1.0	0.2	0.0	1.7	1.7	—	1.4	2.0

No. V and on No. III does not support this theory, for the latter show more injury than the former. Colloidal sulphur and lime-sulphur (1-150) caused no leaf scorch.

The amount of leaf scorch, generally, was greater in 1928 than in 1927, due probably to the very different seasonal conditions prevailing in those years. The hot summer of 1928 would tend to increase the spotting referred to at the outset as common on this variety in drought years.

Estimation of leaf scorch following the pre-blossom application was not made in detail in 1929, but general observations showed that both Bordeaux mixture and lime-sulphur caused slight scorching at this period, as in the previous year. The outstanding result was the very serious damage caused by post-blossom applications of Bordeaux mixture (8-12-100) made with commercial hydrate of lime (quick lime was used in the previous two years), while the trees sprayed with lime-sulphur showed very healthy foliage (see Fig. IV) until the season was well advanced, especially where the applications were preceded by one in the pink bud stage. Colloidal sulphur caused no leaf scorch.

(c) *Fruit Drop.*—The deductions following from the accompanying Table VII are based chiefly on the numbers of fruits *picked*. A record of the number of fruits dropped would, by itself, indicate little, as fruit drop can be attributed to a variety of causes such as heavy cropping, seasonal conditions and attacks by certain insects and some fungi. It is difficult, also, to know precisely when fruit drop, due to spraying, begins and ends, and recording the numbers would be equally difficult. It will be seen that the average numbers of fruit dropped per tree in 1929 (excluding those attacked by Sawfly)* do not give a correct idea of the true situation, as compared with that obtained by

TABLE VII.

Fruit Drop on Cox's Orange Pippin.

Spray Treatment.	Stock.	1927	1928			1929		
		Av. No. fruit picked.	Av. No. blossom trusses.	Av. No. fruit set.	Av. No. fruit picked.	Av. No. blossom trusses.	Av. No. fruit picked.	Av. No. fruit dropped
B.M. +A.1, pre-blossom	IX	19	93	26	5	224	39	24
L.-S. +A.1, pre-blossom		34	55	31	11	182	67	30
Control A.1, pre-blossom		24	91	67	4	192	27	7
B.M. +A.2, post-blossom	V	2	16	4	0	91	14	7
L.-S. +A.2, post-blossom		0	35	32	6	84	20	6
Control A.2, post-blossom		2	40	17	1	109	15	7
B.M. +A. 1 pre- and 2 post-blossom ..	III	0	9	2	0	74	13	10
L.-S. +A. 1 pre- and 2 post-blossom ..		2	21	20	6	157	61	38
Control A. 1 pre-and 2 post-blossom ..		4	31	29	2	166	23	9
L.-S. (1-150) +G.2, post-blossom ..	VI	2	61	20	2	148	14	10
C.S. +G. 2, post-blossom		2	52	13	2	127	12	6
Control G. 2, post-blossom		2	66	21	1	122	15	6

* The total numbers of fruit dropped up to July 24th were recorded. They ranged from ¼ inch (the smallest recorded) to 1½ inches in diameter. All fruits attacked by Apple Sawfly larvæ were omitted from the numbers recorded.

interpreting the results from the numbers of blossom trusses and fruit picked. It was unfortunate that it was found impossible in that year, in the time available, to record the number of fruits set, for this would have given a useful additional basis of interpretation, as it did in 1928.

In 1927, few of the trees had come into bearing. There was a very light crop, except on trees on stock No. IX, and little can be deduced from the results.

In 1928, the average number of blossom trusses on trees that received post-blossom applications of Bordeaux mixture was relatively low; this suggested damage by similar applications in the previous year. This was also shown by the number of fruits set. When the spray was a pre-blossom one, in 1928 (on trees on No. IX stock) it caused damage to the blossoms and thus reduced the number of fruits set. It is evident, from the number of fruits *picked*, that failure to check Scab on the control trees caused the fruits to drop very early; (see Ballou (1), Gossard (7), Malley (9) and Wallace, E. (11) who have all recorded similar results), for, although the trees were relatively rich in blossoms and fruit set, the fruits did not mature in spite of the control of insect attacks by lead arsenate.

Thus, the best crops were picked from trees sprayed with lime-sulphur; injury by Bordeaux mixture or failure to prevent Scab reduced the crop in the other cases.

In 1929, the cumulative effect of damage by post-blossom applications of Bordeaux mixture in previous years was shown by a reduction of the number of blossom trusses on the trees affected (as suggested by Dutton (4)) thus confirming the 1928 observations. Trees sprayed with lime-sulphur again bore noticeably heavier crops than those sprayed either with Bordeaux mixture or with lead arsenate.

There is no consistent evidence that colloidal sulphur caused any damage on this variety.

(d) *Fruit Russeting.*—The amount of fruit russeting was estimated in the same way as the amount of Scab on the fruit, viz., by the "category" method (10). The results in the following Table VIII show the average amount of fruit russeting per group of similarly sprayed trees on the same rootstock.

All the above results show that Bordeaux mixture caused russeting at whatever period it was applied. Thus, even a *pre-blossom* application caused ultimate russeting of the fruit (see Fig. II in Part I (10)) the damage possibly being done before the blossoms had really opened. This result was obtained consistently for three years and is explained by the fact that the spray injures the sensitive skin of the receptacle of the flower so that it cracks while the fruit is developing after fertilization. Careful examination of the receptacles of flowers after a pre-blossom spray showed the presence of the dry deposit of

TABLE VIII.

Fruit Russeting on Cox's Orange Pippin.

Spray Treatment.	Rootstock.	Average " Russeting Equivalent."		
		1927	1928	1929
B.M. +A. 1 pre-blossom	IX	10	15	17
L.-S. +A. ,,		2	4	5
Control A. ,,		5	6	5
B.M. +A. 2 post-blossom	V	20	25	19
L.-S. +A. ,,		5	2	2
Control ,,		5	1	5
B.M. +A. 1 pre- and 2 post-blossom	III	30	—	19
L.S. +A. ,, ,,		0	—	4
Control A. ,, ,,		1	—	5
L.-S. (1-150) +G. 2 post-blossom	VI	3	1	5
C.S. +G. ,,		12	3	2
Control G. ,,		10	5	5

Bordeaux mixture on the skin. Flintoff (5) recorded fruit russeting in pears in W. Australia in 1926, following a pre-blossom application of Bordeaux mixture, but in that case the spray used was much stronger than that used in the present experiments.

Neither lime-sulphur nor colloidal sulphur caused any fruit russeting.

2. STIRLING CASTLE.

This variety was sprayed against Mildew in 1927 and 1928 with various sulphur-containing sprays (see page 285). The injury caused was so severe that it was decided not to spray the trees in 1929.

(a) *Leaf Drop.*—The results for 1927 and 1928 are assembled in Table IX ; they were obtained by the method already described (p. 290).

The results show that lime-sulphur caused most leaf drop. A.P.S. was nearly as harmful, while liver of sulphur and colloidal sulphur caused similar but less damage. All these sprays proved to be quite unsafe for use on this variety at the strengths tested. Lime-sulphur and A.P.S. caused slight leaf drop in 1927 when applied once, pre-blossom. Although giving the best control of Mildew, lime-sulphur can therefore not be recommended for use on Stirling Castle. (See Fig. V and VI.)

Figures were also obtained showing the amount of leaf scorch caused by these sulphur sprays, but as they merely corroborate the above results, they are not presented here.

TABLE IX.

Leaf Drop in Stirling Castle.

Spray Treatment.	Rootstock.	Average No. of leaves dropped.	
		1927	1928
L.-S. + G. 1 pre-blossom	I	387	94*
A.P.S. + G. „		380	215
Control G. „		282	199
L.-S. + G. 2 post-blossom	XIII	1,191	921
Liv. of S. + S.S. „		1,185	503
Control G. „		276	154
L.-S. + G. 1 pre- and 2 post-blossom	XV	1,241	1,257
A.P.S. + G. „ „		968	1,163
Control G. „ „		316	338
L.-S. (1-150) + G. 2 post-blossom	X	1,012	923
C.S. + G. „		659	463
Control G. „		279	227

* Two troughs were damaged and many leaves were lost.

(*b*) *Fruit Drop.*—As with Cox's Orange Pippin, spray injury resulting in fruit drop in Stirling Castle was determined mainly from the number of fruits *picked*. The accompanying Table X shows the results obtained.

In 1927, the crop picked was very light, but the figures show that no fruits matured on any trees that received a post-blossom application of a sulphur-containing spray ; on the other hand the control trees in each case bore a few fruits per tree.

The previous year's spraying with lime-sulphur, liver of sulphur and colloidal sulphur reduced the number of blossom trusses in 1928, indicating that the effect of injury is cumulative. Dutton (4) states that spray injury to apple foliage may check the formation of fruit buds, especially if recurrent year after year. The above results, when studied in connection with those given in Table IX, support this statement.

The number of fruits set was considerably reduced by all applications of fungicides, lime-sulphur again causing the greatest damage in this respect. The records were made after the post-blossom applications had had time to take effect, and this explains why applications given after the fruits had actually formed have apparently reduced the number of fruits set. The visible effect of the sprays followed soon after their application, the newly-formed fruits falling at a touch after a few days.

TABLE X.

Fruit Drop in Stirling Castle.

Spray Treatment.	Root-stock.	1927	1928			1928
		Av. No. fruit picked.	Av. No. blossom trusses.	Av. No. fruit set.	Av. No. fruit picked.	Av. wt. of prunings.
L.-S. +G. 1 pre-blossom	I	6	77	4	4	12
A.P.S. +G. ,,		2	92	15	11	17
Control G. ,,		5	95	19	13	14
L.-S. +G. 2 post-blossom	XIII	0	17	5	0	5
Liv. of S.+S.S. ,,		0	44	7	1	12
Control G. ,,		2	90	22	14	21
L.-S. +G. 1 pre- and 2 post-blossom	XI	0	17	0	0	4
A.P.S. +G. ,, ,,		0	76	2	1	10
Control G ,, ,,		3	77	21	12	14
L.-S. (1-150) +G. 2 post-blossom	X	0	25	7	1	3
C.S.+G. ,,		0	57	31	0	2
Control G. ,,		2	82	49	33	11

The number of fruits matured was reduced to practically nothing on all trees sprayed post-blossom with a sulphur-containing spray. Pre-blossom application of lime-sulphur also reduced the number of fruits ultimately picked.

The final column illustrates the cumulative effect of spray injury in checking new growth, as expressed by the weight, in ounces, of the current year's prunings in 1928. This stunting effect is undoubtedly due to early defoliation. This defoliation and stunting can be seen by comparing Figs. V and VI.

Stirling Castle, therefore, cannot safely be sprayed post-blossom with any form of sulphur commonly used, and the results indicate that it is not safe to spray it even in the "pink bud" stage with lime-sulphur at 1-30.

A preliminary trial indicated that post-blossom Bordeaux mixture is also liable to cause leaf scorch in this variety.

3. OTHER VARIETIES.

Some new and less well-known spray materials, most of them proprietary, were tested on a small scale on some of the new varieties of apples on the Variety Trial plot at East Malling. The sprays were used as recommended by the manufacturers, but it was found that none of them had any definite advantage over Bordeaux mixture or lime-sulphur in controlling Scab, while many of them were definitely harmful.

In 1928 seventy different varieties of apples received a routine, post-blossom application of Bordeaux mixture. The formula was 8-25-100, using quick lime, and one application only was given, viz. on June 6th. No control trees were kept as the spraying was not a quantitative experiment, but observations were made on the effects of the spray on the different varieties. The fruit on about half of the varieties was practically ruined by russeting and cracking, while many of the trees also showed severe leaf scorch. Examination of the russeted fruit revealed the presence of the fungus already mentioned (p. 287), *Coniothecium chomatosporum*: and it was impossible to ascertain whether the damage was due primarily to the spray or to the fungus. Six of the very badly russeted varieties were therefore used in a spraying experiment in 1929 to test the effect of spraying the fruit with Bordeaux mixture. Two trees of each variety were sprayed with this fungicide and two others were sprayed with gelatine solution only, as controls. Hydrated lime was used in the Bordeaux mixture which was thus made according to the formula 8-12-100, and "Spray" gelatine at the rate of 1 lb. per 100 gallons was used as a spreader. One application only was made, viz. on June 21st, about three weeks after petal fall.

The experiment showed that Bordeaux mixture was not safe in 1929 on the fruit of Mr. Prothero, May Queen, Upton Pyne, King Edward VII, King's Acre Pippin and Wagener, and it suggested that the spray, and not the fungus, was the primary cause of the blemish in 1929* because the control fruits were not russeted. This indicates that the routine application of Bordeaux mixture was the primary cause of the russeting in the previous year also.

Routine post-blossom spraying with a proprietary brand of colloidal sulphur (0.5%) +Soft Soap (0.5%) + a proprietary insecticide in 1929, caused extensive damage to a number of varieties at East Malling. The injury took the form of leaf scorch, leaf and fruit drop, and also of a check to the new growth, as illustrated in Figs. VII and VIII (var. Heusgen's Golden Reinette). Some similar trees of this variety on the same plot were not sprayed, and comparison between sprayed and unsprayed shoots demonstrated that the injury was caused by the spray and not by weather conditions. In addition, the spray did not check Scab on several varieties. It should be emphasized that these results were obtained in a single season only.

II. THE EFFECT OF ROOTSTOCK ON SPRAY INJURY.

In these experiments there were no very clear-cut results showing that rootstock has any influence on spray injury, nevertheless the following data on leaf scorch of Cox's Orange Pippin suggest that there may be some influence.

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* The russeting was much more serious in 1928 than it was in 1929 on these varieties, probably because the application of spray in the former year was made at an earlier stage in the development of the fruits than it was in 1929.

TABLE XI.

Leaf Scorch on Cox's Orange Pippin on Different Rootstocks.

Spray Treatment.	Root-stock.	Average leaf scorch after 1st post-blossom application.	
		1928	1929
L.-S. +A. 2 post-blossom	V	2.0	1.4
Control A. ,, ...		1.5	1.3
L.-S. +A. ,, ...	XIII	2.2	1.6
Control A. ,, ...		2.7	2.0

It will be observed from the above figures that both in 1928 and 1929, Cox's Orange Pippin on stock No. V showed more leaf scorch at the same stage, following an application of lime-sulphur, than did comparable control trees sprayed with arsenate only. On the other hand, comparable trees on stock No. XIII, sprayed with lime-sulphur, showed less leaf scorch than did control trees on those rootstocks at the same stage. This suggests the possibility that the rootstock may have had an influence in those cases on the amount of leaf scorch following an application of lime-sulphur. A similar suggestion as to the effect of rootstock is put forward by Frampton (6).

The figures showing the amount of leaf drop in 1929 from trees on the two rootstocks give indications which support the above suggestions. Lime-sulphur-sprayed trees on No. XIII showed slightly less leaf drop than did the comparable control trees, while the reverse was shown by trees on No. V.

III. THE EFFECT OF MANURING ON SPRAY INJURY.

Up to the time of writing data have not been obtained on the possible influence of manuring on the degree of spray injury. An indication that there may be such an influence was obtained in the work of N. H. Grubb in 1929, when the amount of leaf drop from Rival trees sprayed post-blossom with lime-sulphur was much greater on the potash-starved plot than on the potash-fed plot.

IV. SUMMARY AND CONCLUSIONS WITH REGARD TO SPRAY INJURY.

1. Bordeaux mixture has been shown to be quite unsafe to use, at the strengths tested, on Cox's Orange Pippin, as it caused severe leaf scorch and defoliation when applied after blossoming, and fruit russeting and partial loss of crop when applied *before or after blossoming*. The results indicate that the cumulative effect of damage by post-blossom applications resulted in a reduction in the number of blossom trusses produced in the following season. The damage was much more severe in 1929 when hydrated lime was used instead of quick lime.

Some indication was obtained that a pre-blossom application mitigates to some extent the injury due to post-blossom applications.

2. With the exception of trees on No. V rootstock in 1928, when slight leaf drop resulted from post-blossom applications at 1-100, lime-sulphur produced no injury to the trees. In general they have consistently borne more fruit than other trees in the experiment ; the fruit has not been blemished by russeting, and the foliage has been healthy. Three applications of lime-sulphur, the first at the " pink bud " stage at 1-30, the next at petal fall at 1-100, and the third three weeks after this at 1-100 are therefore recommended for the control of Scab on this variety. Lead arsenate at 4 lbs. per 100 gallons before blossoming and 3 lbs. per 100 gallons after blossoming was incorporated with the lime-sulphur in these experiments and should be used if deemed necessary. There were slight indications that its inclusion increases the effect of lime-sulphur against Scab.

3. There was no consistent evidence that colloidal sulphur (0.4%) caused any damage on Cox's Orange Pippin.

4. The experiments showed that it is not safe to spray Stirling Castle with any of the generally-used sulphur-containing sprays after blossoming, on account of very severe leaf drop, reduction in the number of fruit buds subsequently formed, and fruit drop. There is evidence that a pre-blossom application of lime-sulphur at 1-30 in the " pink bud " stage is also unsafe on this variety.

5. Several proprietary sprays were tested on some of the newer varieties of apples, and while none of them showed any distinct advantage over Bordeaux mixture or lime-sulphur in controlling Scab, some proved, in the one season tried, to be distinctly harmful to the varieties on which they were tested at strengths recommended by the manufacturers.

6. There is some evidence that the variety of rootstock may influence the amount of leaf scorch on Cox's Orange Pippin following an application of lime-sulphur.

7. Data on the possible influence of manuring on spray injury were not obtained in the experiments described in this paper, but another experiment at East Malling suggests that a relation between the two exists.

GENERAL SUMMARY.

APPLE SCAB.

The " category " method employed in estimating the severity of attack by this disease on young shoots, leaves and fruit is described, and the results obtained are correlated with seasonal conditions, spraying, type of rootstock and manuring. The conidia of the apple scab fungus are dispersed from the pustules on the young wood over a period of many weeks, because the pustules are not simple structures, but are composed of a series of pads of mycelium which burst through the bark in succession and liberate their conidia. Spraying in the " pink bud " stage has nevertheless proved to be sufficiently early to give efficient protection from infection under East Malling conditions, and is regarded as being of great value because it is applied at a critical period when Scab, in favourable weather, may become epidemic and cause much loss due to flower and fruit drop.

The value of different spray fluids in controlling Scab is discussed, and a " pink bud " application of either lime-sulphur or Bordeaux mixture is shown to be very important. Bordeaux mixture with lead arsenate applied three times, once in the " pink bud " stage at 8-8-100 (quick lime) and twice after blossoming at 8-25-100 (excess quick lime), gave the best results. It cannot be recommended for Cox's Orange Pippin, however, owing to the severe damage it causes. It is shown that the spray russeted the fruit severely *even when applied only in the pink bud stage*, and it caused leaf scorch and defoliation when applied after blossoming. The results also suggest strongly that the cumulative effect of previous years' damage by post-blossom applications of Bordeaux mixture resulted in a reduction in the number of blossom trusses subsequently produced. This spray also considerably reduced the crop on this variety.

Lime-sulphur with lead arsenate, applied at the same three stages, at 1-30 before, and 1-100 after blossoming, gave very good control and caused no serious damage to Cox's Orange Pippin trees. There is evidence that a pre-blossom application mitigated to some extent the amount of leaf drop caused by post-blossom applications. For this variety, lime-sulphur was considerably reduced in strength for post-blossom applications, for safety's sake, but this undoubtedly impaired its fungicidal value.

Colloidal sulphur showed some control, and was approximately equal in efficiency to lime-sulphur at 1-150, both being applied post-blossom. These sprays caused no damage. There is some evidence that the efficacy of lime-sulphur against Scab on the leaves was increased by the addition of lead arsenate.

The effect of seasonal conditions on the results obtained by spraying is pointed out.

Several proprietary sprays were given a trial, but none of them showed noteworthy advantages over Bordeaux mixture or lime-sulphur, while some caused damage. A preliminary trial of sulphur " dusts " against Scab in 1929 indicated that they were in general slightly inferior to lime-sulphur at 1-100 as post-blossom applications, while there was no evidence of damage by any of the treatments. Infection by Scab on the control trees was slight.

The variety of rootstock on which trees are worked has been shown to influence the degree of infection by Scab. Evidence is put forward to show that the effect of spray treatment was not necessarily the same on trees of Cox's

Orange Pippin on different rootstocks, and other data indicated that in 1929 there was a differential reaction by rootstock to the manuring of Bramley's Seedling on No. I stock.

A year's detailed records of the amount of infection on the fruits of Bramley's Seedling and Worcester Pearmain show that two applications of lime-sulphur, one before and one after blossoming, gave good control of Scab on a plot that had received complete manurial dressings for a period of years, while the same spray programme did not prevent a very heavy infection by Scab on comparable trees of the same varieties on a plot which had received no manurial dressings over the same period. The year's figures are supported in general by certain records taken of the percentage of scabbed fruit from the same trees of Worcester Pearmain during the previous year.

APPLE MILDEW.

Bordeaux mixture, lime-sulphur and colloidal sulphur were tested on Cox's Orange Pippin for Mildew control, and although really first-class control was not given by any of them, three applications of lime-sulphur, without arsenate, were the most efficacious. Various sulphur-containing sprays were used on Stirling Castle as pre- and post-blossom applications, but none of them proved safe after blossoming on this variety. Lime-sulphur, at 1-30, *before* blossoming caused direct damage to the trees, injuring the blossom trusses and reducing the number of fruit set.

Soda-soap solution (20-10-100), in comparison with several less-known sprays, was tested on trees of Belle de Boskoop, against Apple Mildew because of its success against American Gooseberry Mildew ; but, while considerably reducing the number of infections as compared with the number on the control trees, it caused severe damage by fruit drop. None of the other treatments was very successful, and a few caused loss of crop.

The rootstock on which the tree is worked has been shown to influence the degree of infection by Mildew on the scion variety, Cox's Orange Pippin being noticeably susceptible on No. I rootstock. Manurial treatments did not show any definite influence on the number of infections of Mildew on Bramley's Seedling in 1928, when the number was regarded in relation to the size of the trees expressed in terms of girth measurement.

ACKNOWLEDGMENTS.

The writer wishes gratefully to acknowledge much kindly help, advice and criticism received from the Director of East Malling Research Station, Mr. R. G. Hatton, and from Dr. G. H. Pethybridge, Dr. H. Wormald and Mr. R. V. Harris. He is also indebted to Mr. T. N. Hoblyn for statistical analysis of the figures.

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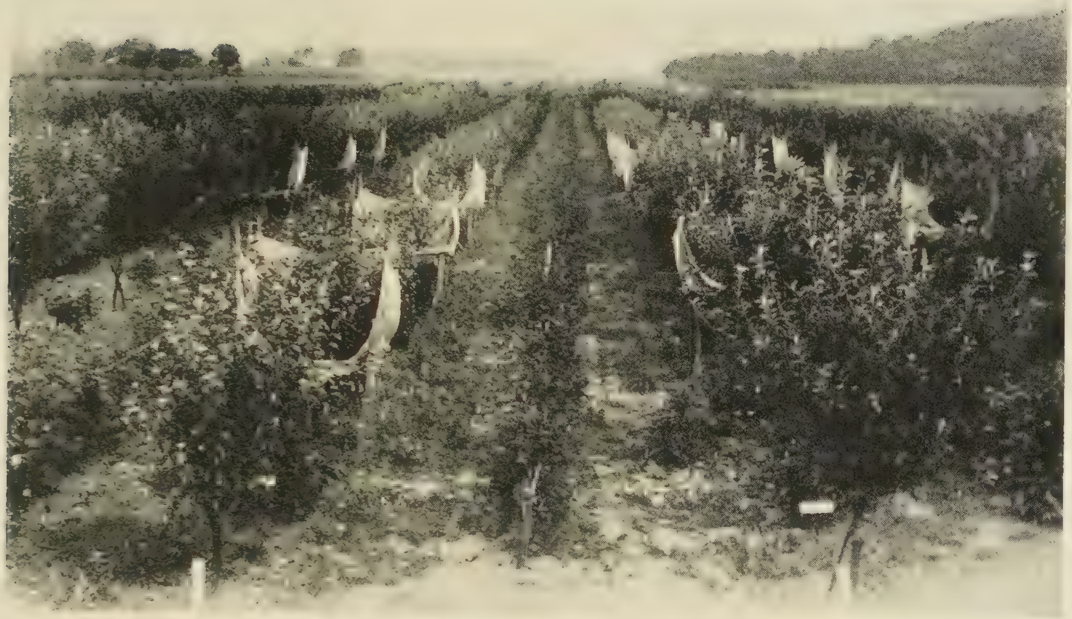
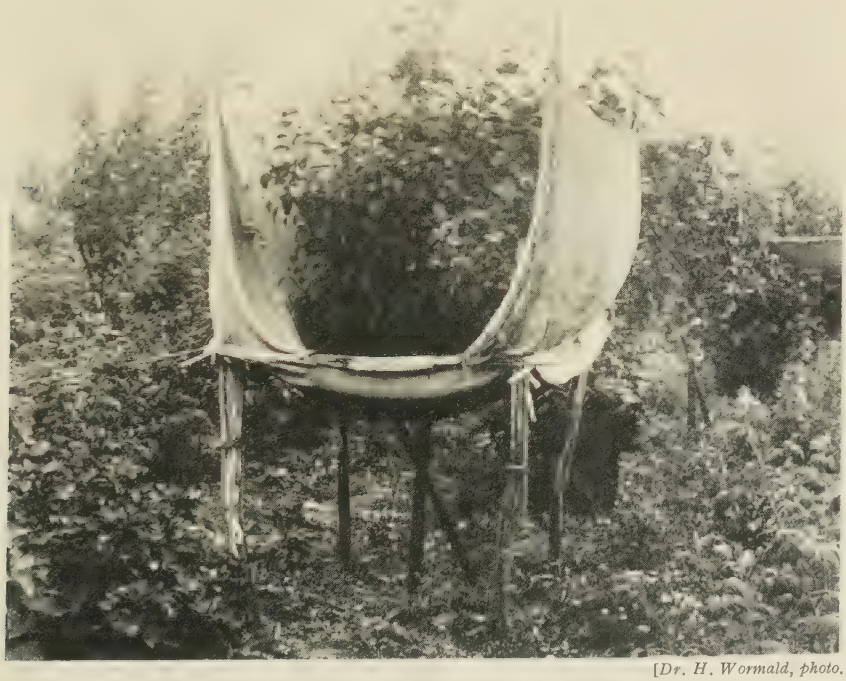


[*Dr. H. Wormald, photo.*

FIG. I.

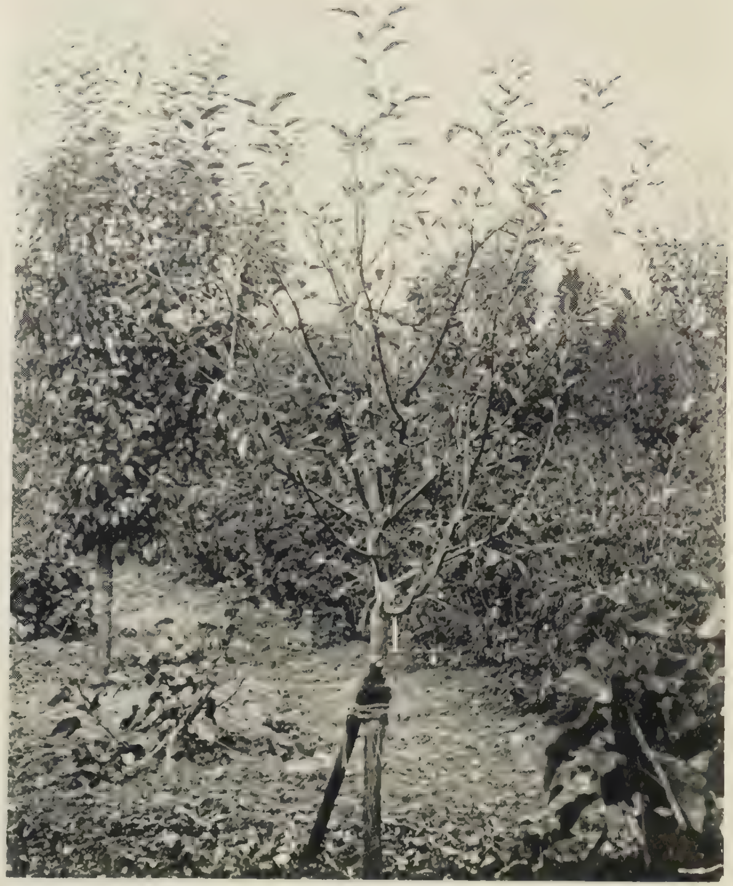
General view of the spraying trial plot, showing hessian troughs in position on certain trees.



[*Dr. H. Wormald, photo.*

FIG. II.

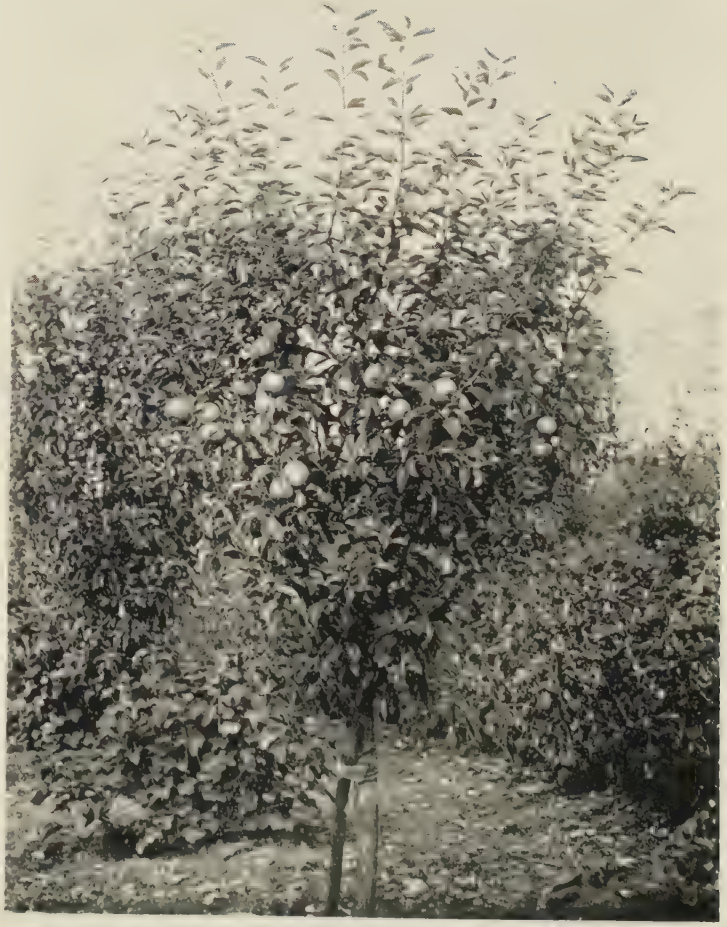
Near view of Stirling Castle tree, with hessian trough, showing construction.



[M. H. Moore, photo.

Fig. III.

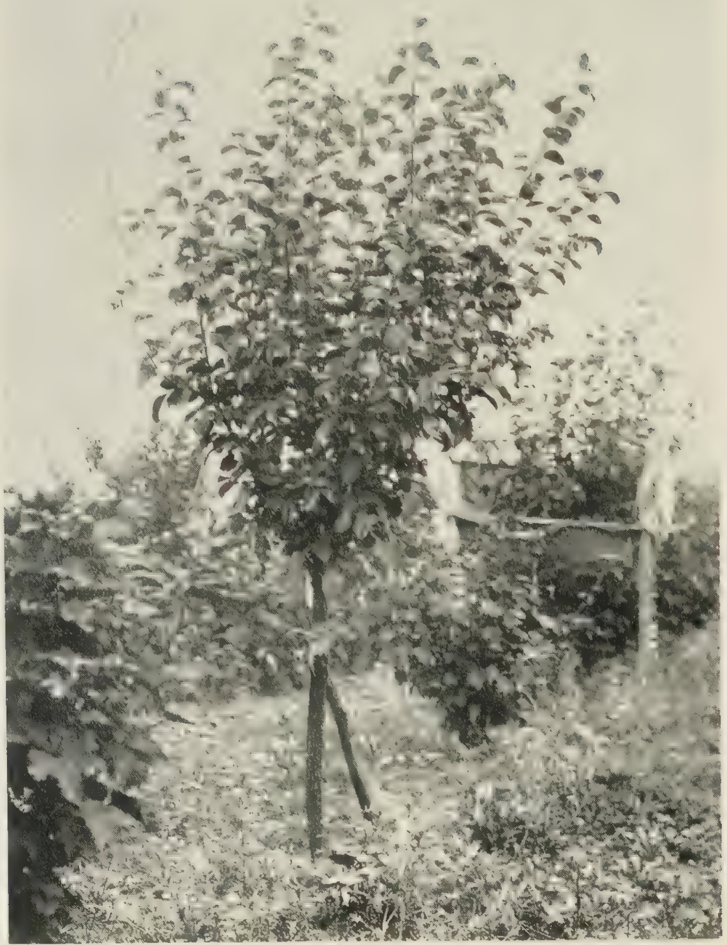
Tree of Cox's Orange Pippin on No. III Stock, sprayed three times with hydrated lime Bordeaux mixture (8–12–100) and lead arsenate, in 1929. Note the loss of foliage.



M. H. Moore, photo.

Fig. IV.

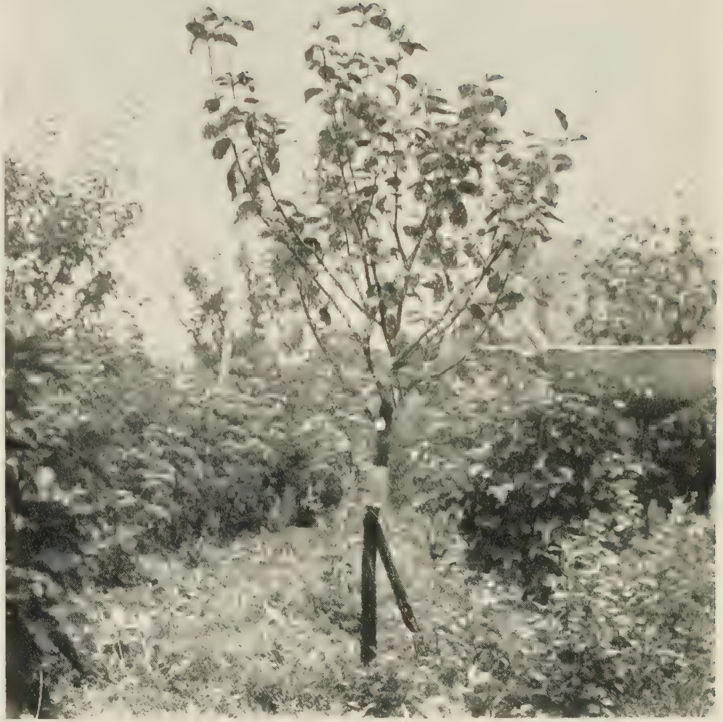
Comparable with Fig. III, but sprayed with lime-sulphur and lead arsenate. No injury and no Scab.



[Dr. H. Wormald, photo.

FIG. V.

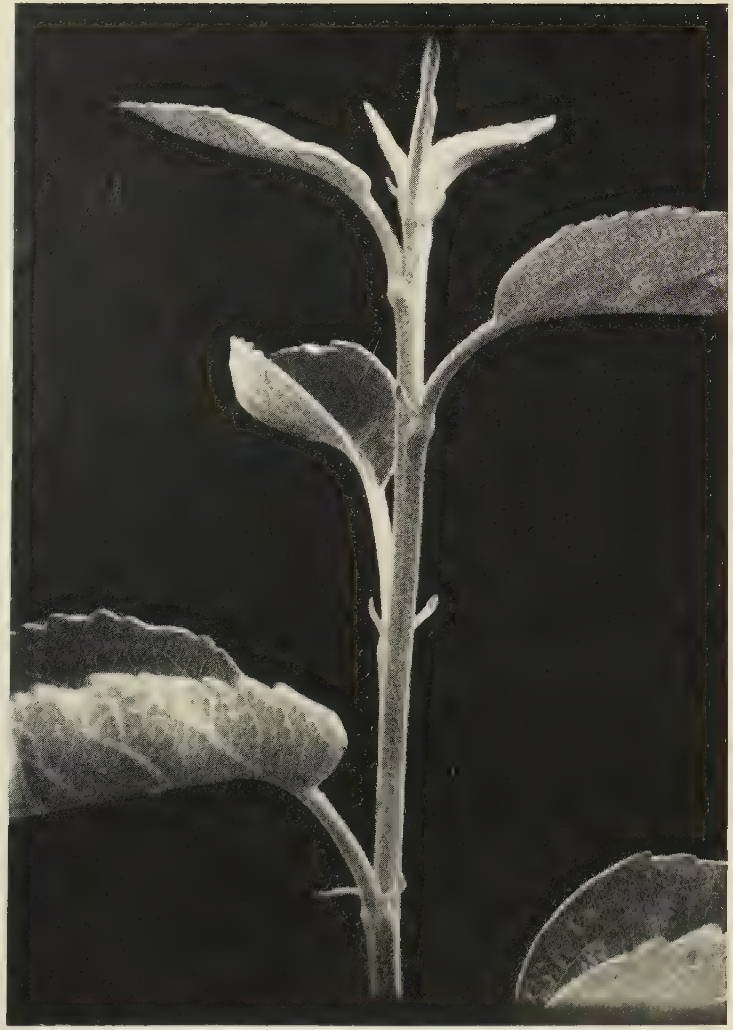
Stirling Castle tree sprayed with gelatine solution only (control).



[Dr. H. Wormald, photo.

FIG. VI.

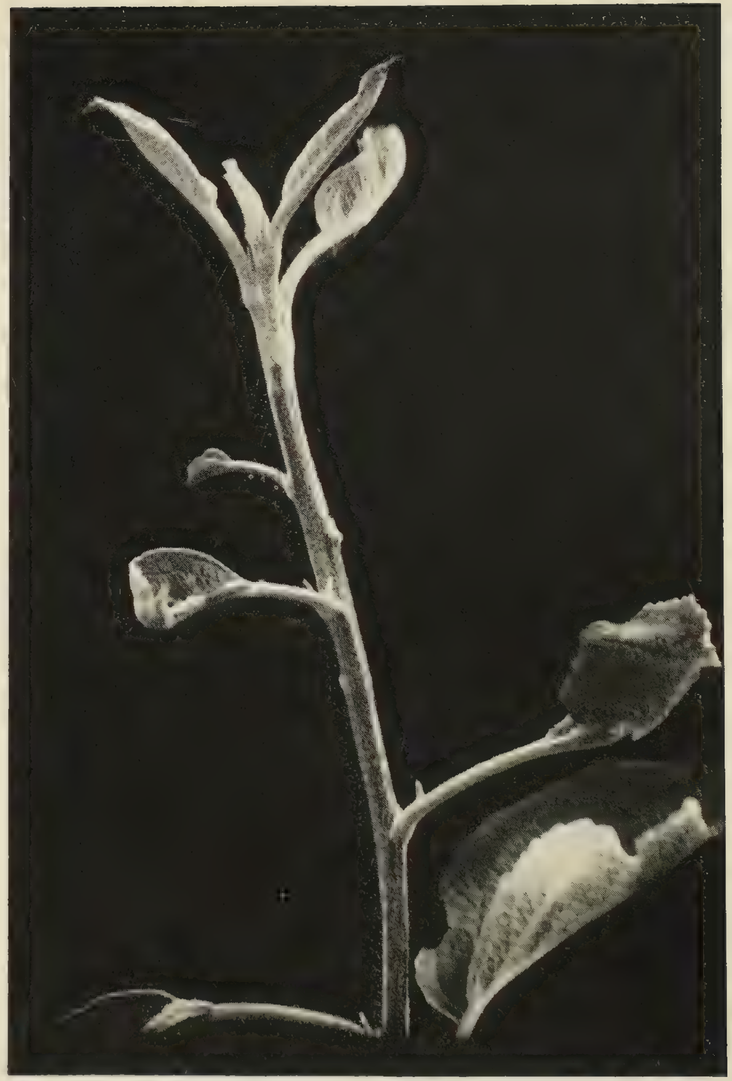
Comparable with Fig. V, but sprayed twice, post-blossom, in 1926 and 1927 with lime-sulphur (1–100) and gelatine (0.1%). Note defoliation and stunting of growth.



M. H. Moore, photo.

FIG. VII.

Young shoot of Heusgen's Golden Reinette, unsprayed, 1929.



M. H. Moore, photo.

FIG. VIII.

Comparable with Fig. VII, but sprayed with colloidal sulphur (0.5%) +

THE TARSONEMID MITE OF STRAWBERRY.

By A. M. MASSEE.

East Malling Research Station, Kent.

A NOTE* appeared in *The Gardener's Chronicle* last January recording the presence of a Tarsonemid Mite (*Tarsonemus fragariæ* Zimm.) upon the cultivated strawberry in England. Although very little was known about the mite at that time, it was pointed out that the same mite occurred in Germany, Sweden, Denmark, Norway and Russia and in those countries it seemed to be of definite economic importance. Recently the same species has been found in Holland.

The Tarsonemid Mite appears to be established in widely separated strawberry growing districts in this country. At present it has been recorded from East Malling, Maidstone, Leeds, Chislehurst and Sevenoaks (Kent); Scaynes Hill, Chailey and Lewes (Sussex); Wisbech (Cambridge); Hele (Devon); and from Truro (Cornwall).†

In most cases the mite has been found upon the variety Royal Sovereign, but it is not confined to this variety alone since it has been recorded on Paxton and Laxtonian.

A closely allied mite (*Tarsonemus pallidus* Banks)‡ has been found on cultivated strawberries in the United States of America and in Canada. In these countries the mite is regarded as a field pest of the strawberry plant, and investigations are in hand to determine whether the mite is responsible for the failure of the plants in some instances.

A comparison of the European and the Canadian species of mite has been made possible through the courtesy of Mr. W. A. Ross, Entomologist, Vineland Experimental Station, Ontario, Canada. The material received from Mr. Ross proves to be quite distinct from the European species. However, it is not surprising to find two distinct species of the same genus attacking the same host plant.

T. fragariæ Zimm. and *T. pallidus* Bks. may be distinguished from a systematic point of view by the characteristics of the posterior pair of legs of the males.

The third joint of the fourth pair of legs of *T. fragariæ* Zimm. bears two strong, stout fingers; a fine, short hair; and a very long bristle which is acuminate at apex. The third joint of the fourth pair of *T. pallidus* Bks. possesses two short spines, which are very much weaker than those of *T. fragariæ* Zimm. A short, clavate hair is present and also a very long thread-like hair.

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* The Occurrence of a Tarsonemid Mite upon the Cultivated Strawberry in England. A. M. Massee. *Gar. Chron.*, Vol. LXXXVII (3rd Ser.), No. 2,250. pp. 110-111.

† While this paper was in the press the mite was found on strawberry leaves received from thirty more localities, and it seems to be present in the majority of districts where Royal Sovereign is grown. A.M.M.

‡ The Cyclamen Mite (*Tarsonemus pallidus*) as a Field Pest of the Strawberry Plant. Geo. M. Darrow. U.S.A. Dept. Agric., Nov., 1928 (a stencilled memorandum with 2 figs.).

The second joint of hind leg of male *T. fragariæ* Zimm. bears a very strong, short bristle at base, while the corresponding joint of *T. pallidus* Bks. bears a long, tapering bristle at base, and also a fine hair towards apex. The characters referred to above are sufficient for separating the two species. The females of the two species are very much alike, and so far no character has been observed to separate the species correctly.

Observations in the field in this county have shown that the mite occurs in greater numbers upon unhealthy plants and in view of this important fact a preliminary experiment has been undertaken to determine the nature of damage, if any, caused by mite upon the strawberry plant.

For this purpose twenty-four healthy Royal Sovereign strawberry plants, growing in pots were selected and kept in an insect proof greenhouse. The plants were divided into two batches of twelve, one batch being infected with mites and the other being left untreated as a " control " to the former series.

Although all the plants were known to be free from attacks of Aphis, Red Spider and the Tarsonemid mite they were thoroughly well sprayed with lime-sulphur and a white oil emulsion spray as a final precaution. The control plants were kept at some distance from the infected ones, and were sprayed each week from the beginning of May to prevent any possibility of mite infection. The pots were grease-banded also to prevent any insects or mites from reaching the plants from the staging.

Three female tarsonemid mites were placed on a young unopened leaf of each of twelve plants to be infected. The first infection was made on May 7th. The infections were repeated on the 10th and 13th of May. In the latter infections approximately six mites were placed on the foliage of each plant.

A week later the plants were examined in detail and living mites were found on each plant. Eggs were present on the foliage of some of the plants, and on one plant immature mites were present.

By the end of June all the plants in the infected series were literally covered by adult and immature mites and their eggs. It seems quite evident, at least under greenhouse conditions, that the mites breed very rapidly and when it is remembered that only nine female mites were put on each plant, the rate of reproduction must be enormous. Up to the time of writing a male tarsonemid mite has not been found on any of the plants, which indicates that the female can breed without the presence of the male. The control plants have been examined at frequent intervals throughout the season and it may be said quite definitely that they have not been attacked at all by any species of aphis, red spider or mite.

The first sharp distinction between the infected and the control plants was noticeable by the first week in July. The control plants were producing many sturdy runners and the foliage was of a fresh green colour. On the other hand the infected plants were weakened very considerably and the foliage was of a dull silvery green colour. The runners were very much distorted and weak. At the end of July all the control plants were still quite normal, and healthy runners were still growing quite freely.

By this time the infected plants were all in a very unhealthy condition, and the silvery appearance of the foliage gave one the impression that they were badly affected by mildew. Most of the young leaves were weak, deformed and brown in colour. The older leaves were all crinkled, of an olive green shade, with the edges a sickly yellowish green. In addition to the crinkling the edges of the leaves are turned upwards (spoon shaped) and the texture becomes very brittle. In very many cases the newly developing leaves turn a silvery-brown colour and remain dwarf. Sometimes these leaflets do not develop and those very badly affected dry up completely. (See Fig. I.)

Exactly the same description can be given of the runners. All the developed leaves on the infected runners show the typical crinkled appearance, the texture becomes very brittle and the plants are very dwarfed and stunted.

Unhealthy plants have been found in the field showing symptoms exactly similar to those described above, and in each case the Tarsonemid mite has been present. This fact may prove to be of considerable importance to the strawberry grower.

NATURE OF ATTACK.

One very important point that must be emphasized is the way in which the mite attacks the plants. All the damage caused to the leaves by the mites is done in the very early stages before the leaflets are unfolded. When the leaves are fully opened, very few, if any, mites are to be found upon them. As mentioned in the previous article, all tarsonemid mites dislike strong sunlight, and therefore seek shelter in the unfolded leaves, where they feed and breed. Exactly the same thing happens to the runners. The damage is completed before leaves are developed, and as a result the runners are somewhat weak and difficult to establish. There is a natural migration of mites from the parent plant to the runners as soon as they begin to grow.

It is quite possible that this mite has been present in this country for many years, but has been overlooked on account of its obscure habits.

Although the mites prefer sheltered places for breeding purposes, it is evident that they can travel very quickly, because they are always to be found on young runners as soon as they are produced.

Twenty-four self infested runners have been raised from the infected plants for observation purposes. Of these, eight have died and the remainder are in a very unhealthy condition. There is little doubt that the plants were killed as a result of mite attack. It should be mentioned that the mite infestation was very severe under the greenhouse conditions and it is unlikely that the plants would have died had they been growing in the field.

Thirty-six runners were raised from the healthy " control " plants (many more could have been raised if desired) and it is proposed to use these for the continuation of the experiment next year. These runners will be especially valuable since they are selected plants and are definitely known to be free from any kind of insect or mite attack.

Although it is not possible to form any definite opinion from the result of one year's investigation, there is reason to believe that the Tarsonemid mite (*Tarsonemus fragariæ* Zimm.) may be one of the causes of the failure of strawberry plants in this country.

The writer is indebted to Mr. W. Steer for taking the photograph and to Mr. A. Tidy for the interest and untiring energy he has displayed in tending the plants from the cultural point of view.

SUMMARY.

In a preliminary experiment healthy Royal Sovereign strawberry plants became diseased and malformed when attacked by the strawberry mite (*Tarsonemus fragariæ* Zimm.).

As a result of mite attack the leaves become crinkled and very brittle. Newly developing leaves turn a silvery-brown colour, and in some instances dry up.

Attacked runners are also malformed and as a result unhealthy plants are produced.

All the " control " (non-infected) plants remained perfectly healthy and produced healthy runners.

(*Received* 15/9/30.)

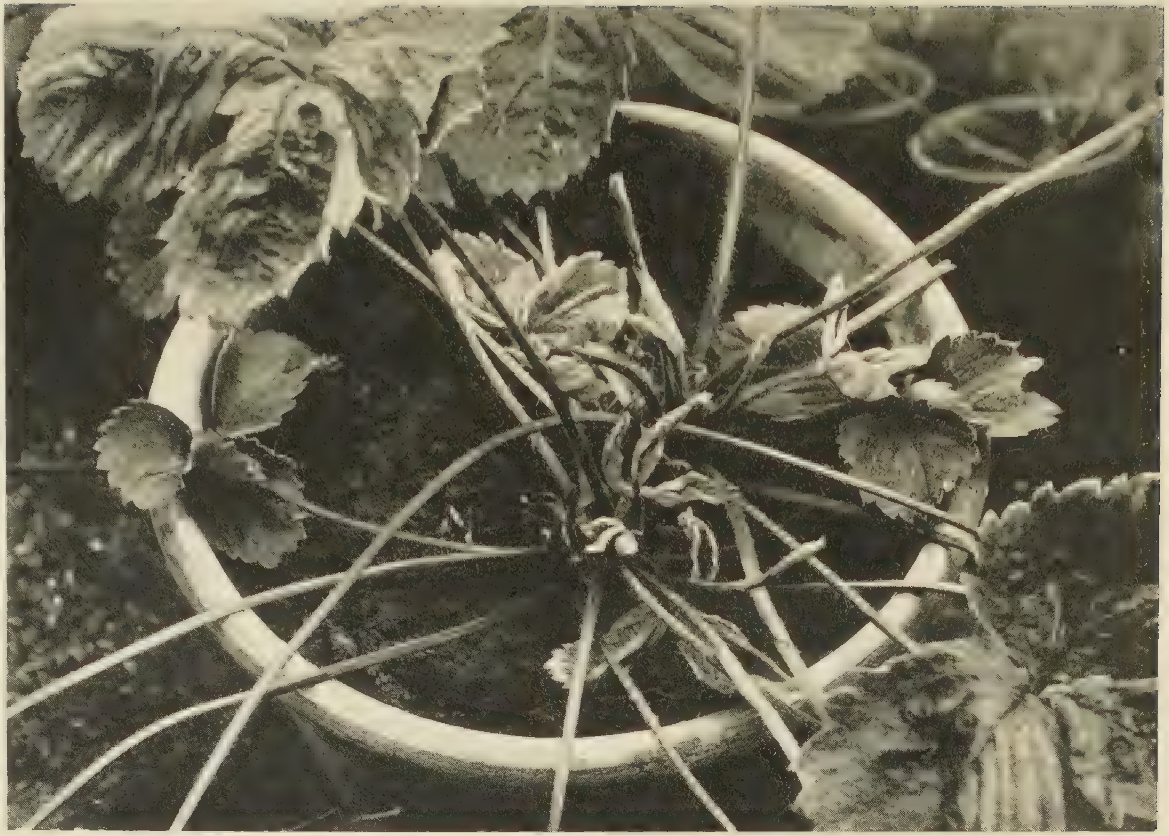

Photo. W. Steer

A Mite-infested Royal Sovereign Strawberry Plant.

THE RASPBERRY AND LOGANBERRY BEETLE AND ITS CONTROL.

FURTHER EXPERIMENTS WITH PYRETHRUM EMULSION SPRAYS AND A DUST.

By C. L. WALTON, M.Sc., Ph.D.
Long Ashton Research Station.

Introduction.

The result of experiments on the control of the Raspberry and Loganberry Beetle carried out during 1928 and 1929 appeared in the *Journal of Pomology and Horticultural Science* for May, 1930 (1). It was there shown that a "commercial" control of *Byturus tomentosus* could be obtained by three successive applications of a pyrethrum emulsion spray when approximately one-third, two-thirds, and all the flowers were fully open. This spray has the advantage of being non-poisonous, and is harmless to flowers and foliage. Recent experiments indicate that the honey bee is apparently not affected by Pyrethrum vapours (2).

Satisfactory as these results were, it was nevertheless resolved to carry out a further series of field trials during 1930 for the following reasons : The trials of 1928 were of a purely initial character, and since in the more extensive series of 1929, the principal one was on Raspberries it was felt that a more extensive trial should be conducted on Loganberries. Furthermore, it afforded an opportunity for the trial of Pyrethrum in more varied forms.

Field Trials in 1930.

These trials included the following. (1) An emulsion spray precisely similar to that used in the previous trials and made up according to the formula published by Tutin (3) and (4). This spray when needed for use in the field requires the addition of caustic alkali and is hence of the "two solution" type. This is referred to in the Diagram and Table A as Spray I. (2) A spray made up from a concentrated extract and prepared in such a way that it emulsified on being mixed with water, thus obviating the somewhat troublesome business of adding caustic alkali in the field. This spray is described as Spray II in the Diagram and Table A. (3) A dust in which the active principles of the Pyrethrum flowers were incorporated with a carrier. This dust is of such a strength that ten parts represent the active principles of one part of Pyrethrum flowers.

The trial centres utilized were three, namely, one in Herefordshire for the main trial on Loganberries, in which all the forms of Pyrethrum enumerated were included, and where both the sprays and the dust were applied three times ; and two at Long Ashton, for subsidiary trials, one on Loganberries and one on Raspberries. In both these latter only the dust was employed, the reason for this being that it was of considerable commercial importance to discover whether the dust would be as effective as the wet spray, owing to the comparative ease with which it could be applied as compared with the latter.

Trial I.—Breinton Manor, Hereford.

Layout of Trial.—The trials here were on Logans. The lay out is shown in the accompanying diagram and the Results are in Table A.

Reference to the diagram will show that the rows of Logans adjoining an apple plantation were selected for trial. This was done because experience has shown that infestation is usually most severe in the vicinity of apple, pear, hawthorn, etc., and this proved to be the case. The first six rows were treated with the exception of a central untreated block left as a control. In order to obviate any effects on results from drifting dust or spray the next six rows were left to act as a " buffer " and not taken into account. Finally the remaining spray was applied to a part of each of the following six rows, the unsprayed portion of which served as a separate control.

Sprays and dust were applied in suitable weather to all plots on June 5th, 12th and 19th-20th, when approximately one-third, two-thirds and the whole of the flowers respectively were fully open. The sprays were applied by means of a power sprayer and four spray guns, working at a pressure of 100 to 150 lbs., and the dust by means of efficient " knapsack " dusters.

The dates of the counts are given in Table A. The total number of fruits examined was 17,000. All counts were " random samples " and all the fruits were examined on the spot.

Observations on Results.

Sprays.—It will be seen that both the sprays employed gave satisfactory results. It will further be noted that there was a very marked difference in the degree of infestation between rows 1-6 (next to the apple trees) and rows 12-17, the average infestation on the former being over 30 per cent. whilst on the latter it was barely 10 per cent.

Dust.—This gave results of a much inferior character, as compared with the sprays. Furthermore, the carrier employed adhered very firmly to both fruits and foliage and, in spite of subsequent heavy rain, rendered the former unsightly for the greater part of the picking period.

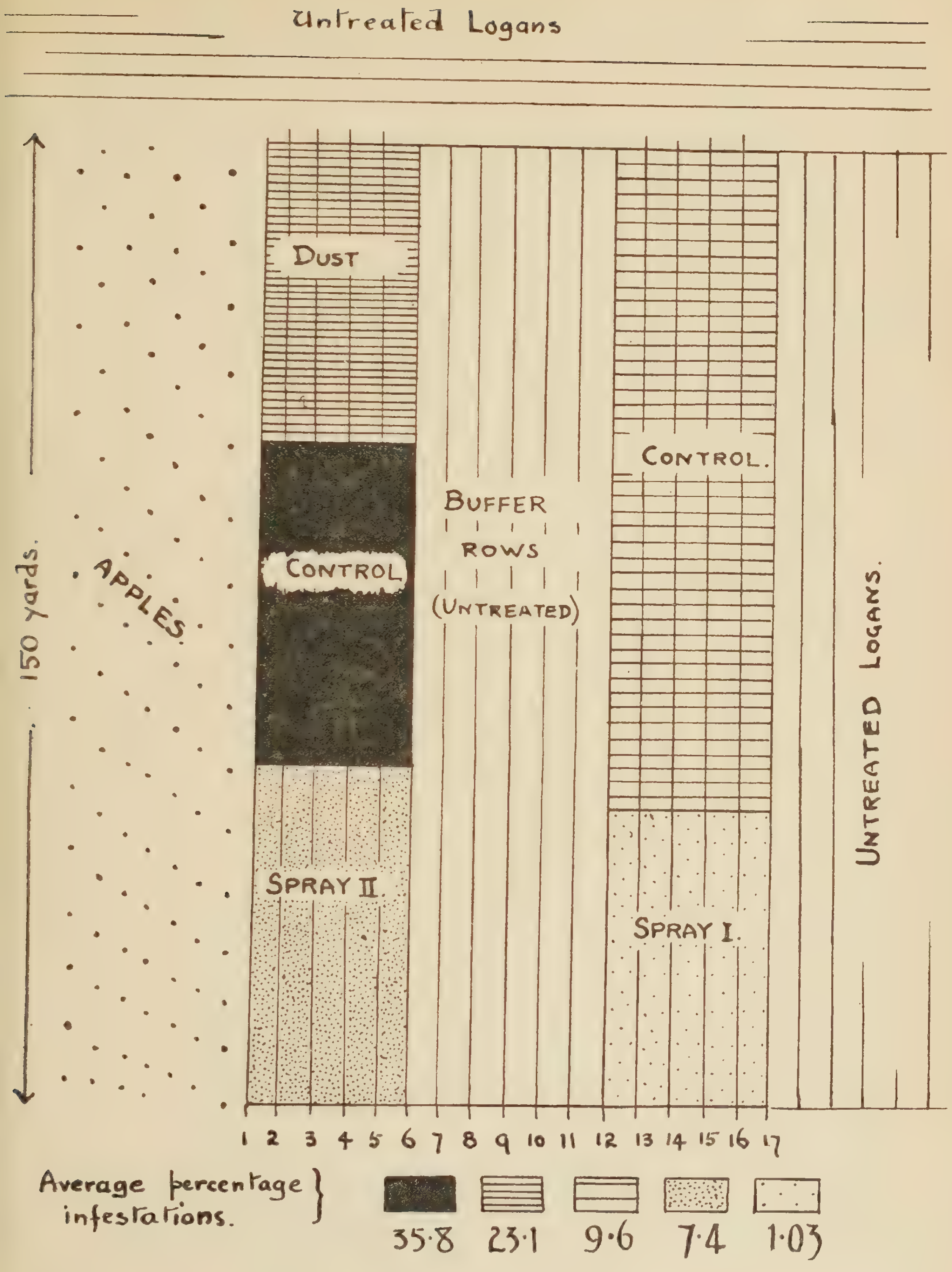
Untreated Logans
150 yards.
Apples.
Dust
Control
Buffer
Rows
(Untreated)
Control.
Spray II.
Spray I.
Untreated Logans.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Average percentage infestations.
35·8
23·1
9·6
7·4
1·03

TABLE A.

Loganberries—Breinton Manor, Hereford.

Date of Picking ..	July 14.	July 16.	July 18.	July 21.	July 25.	July 28.	Aug. 1.	Aug. 6.	Aug. 11.	
No. of Fruits examined per Plot	500	300	300	400	400	400	400	400	300	Totals per Plot. 3,400
Percentage Infestation Control A.	59·4	55·0	54·0	45·5	34·5	23·3	17·0	10·7	6·7	Average Infestation. 35·8
Dust	34·8	31·3	30·7	35·5	27·5	24·5	12·0	6·7	5·2	23·1
Spray II (One Solution)	5·0	9·3	7·3	9·5	6·0	8·3	7·5	6·7	7·5	7·4
Control B.	13·8	11·3	11·3	14·6	9·7	10·2	6·7	5·6	3·7	9·6
Spray I (Two Solution)	1·0	·3	·3	—	·7	1·0	2·0	1·5	2·5	1·03

Trial II.—Gardens at Long Ashton.

Lay-out of Trials.—This trial was carried out in two heavily infested private gardens, situated near one another in the village of Long Ashton. The dust only was used. Each trial was conducted on a short row of Logans a portion of which was sprayed and the remainder left unsprayed as a control. The relatively short picking period (as compared with the commercial plantations at Hereford) is accounted for largely by the very dry conditions which had prevailed, and it may be noted also that picking commenced a fortnight earlier than at Hereford. The dust was applied by means of a small hand machine on June 1st, 4th and 6th for Garden I; and on the 2nd, 10th and 16th for Garden II. The total number of fruits examined was 1,883 for Garden I and 3,419 for Garden II=total 5,302. The results are set out in Table B.

TABLE B.

Pyrethrum Dust—Loganberry Fruit Counts.

Gardens in Long Ashton.

Date of Picking.	Percentage Infestation.	
	Control.	Dusted.
Garden I. :		
4/7/30	86.0	53·3
7/7/30	86.4	57·4
11/7/30	83.0	71.6
15/7/30	89.4	84.3
Average	86.2	66.6
Garden II. :		
7/7/30	59·2	31·3
10/7/30	60.2	37·1
15/7/30	62.5	46.2
18/7/30	68.3	59·2
Average	62.5	43·4

Observations on Results.

It will be seen that the average reduction of infestation was only about 20 per cent., and that in spite of the three applications, the infestations remained comparatively high. Here also the same unsightly effect of the dust previously mentioned was apparent.

Trial III.

Lay out of Trial.—This trial was designed to determine (a) the effect of the dust on raspberries as compared with logans, (b) the effects of a single application and (c), by the inclusion of three varieties (Lloyd George, Baumforth A and Duke of Cornwall) whether the different varietal forms of flower would have any effect on the result. In Duke of Cornwall the flower is of a more open type; this, it was expected, would result in the lower infestation after treatment, since (1) less shelter is afforded to egg-laying beetles and (2) the dust could reach the beetles with greater ease.

The dust was applied on June 2nd and 3rd, by means of knapsack dusters. The total number of fruits subsequently counted was 4,565.

TABLE C.

Pyrethrum Dust—Raspberry Fruit Counts.

Long Ashton Experimental Station Variety Trials.

Variety.	Date of Picking.	Percentage Infestation.		Difference in Infestation.	Percentage Reduction in Infestation.
		Control.	Dusted.		
Lloyd George ..	1/7/30	32.5	19.5	13.0	40.0
	4/7/30	42.2	22.9	19.3	45.7
	7/7/30	28.9	16.8	12.1	41.9
	9/7/30	23.0	21.5	1.5	6.5
Average		31.6	20.1	11.4	33.5
Baumforth A. ..	4/7/30	33.6	23.1	10.5	31.2
	7/7/30	31.0	16.1	14.9	48.1
	9/7/30	20.5	21.0	—	—
Average		28.3	20.0	8.4	39.6
Duke of Cornwall ..	4/7/30	27.9	10.3	17.6	63.9
	7/7/30	22.3	12.7	9.6	43.1
	9/7/30	14.5	8.0	6.5	44.8
Average		21.9	10.3	11.2	50.6

Observations on Results.

Here again the reduction of infestation, although somewhat higher than in the case of the Logans, was much inferior to that obtained by means of the spray. The expectation that infestation would be lower in Duke of Cornwall was to some extent borne out, whilst the reduction of infestation was also slightly greater.

GENERAL REVIEW AND CONCLUSIONS.

The results detailed show that both sprays gave excellent results, thus bearing out the figures of the two previous years.

On Logans average infestations of 35.8 per cent. and 9.6 per cent. were reduced to 7.4 per cent. and 1.0 per cent. respectively. It is notable also that this was during a period extending from July 14th to August 11th, covering almost the entire cropping period.

In view of these results it is felt that these sprays are worthy of extended trials by growers since the figures obtained indicate that infested areas so treated should be sufficiently freed from the pest for the crops to be suitable for canning and bottling operations. These Pyrethrum Emulsion sprays moreover possess the advantage of being non-poisonous, do not scorch foliage, or impart any adverse colour or flavour to the fruit.

The results given by the dusts were in no way equal to those obtained with the sprays, and the carrier employed adhered to the fruit, giving it a grey appearance.

ACKNOWLEDGMENTS.

Thanks are due to the British Dyestuffs Corporation Ltd. for supplying the materials necessary for the two solution mixture (Spray I), and also to Messrs. Stafford Allen & Sons for preparing the concentrated extract which emulsified directly with water (Spray II) and also for the Dust.

Acknowledgment must again be made to Mr. G. Marshall, Breinton, Hereford, and his sons, for the large amount of trouble taken in connection with the main Loganberry trial, also similarly to Prof. B. T. P. Barker and Mr. G. T. Spinks in connection with the smaller trials.

Finally, I must thank Mr. Edward McC. Callan for the great assistance he gave in collecting the data set out in the Tables.

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INVESTIGATIONS ON THE NUTRITION OF FRUIT TREES.

SOME EFFECTS OF DEFICIENCIES OF NITROGEN, POTASSIUM, CALCIUM AND MAGNESIUM, WITH SPECIAL REFERENCE TO THE BEHAVIOUR OF CERTAIN VARIETIES OF APPLE TREES.

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In previous numbers of this Journal (1, 2, 3) nutritional experiments on apple trees have been described by Wallace of the Long Ashton Research Station. In (3) analyses of the ash of certain portions of trees subjected to deficiency treatments were recorded.

As these articles have given a review of the literature available on this type of work with fruit trees, it is unnecessary to repeat further here.

The present paper deals with a study of the effects of omission of nitrogen, potassium, phosphorus, calcium and magnesium from a complete nutrient solution and of using rain water only, on the three varieties of apple trees, Bramley's Seedling, Worcester Pearmain and Allington Pippin.

The special points on which information was sought were as follows :—

How far the results recorded in (3) with Stirling Castle would hold for other varieties ; whether any significant range of resistance to the various omission treatments exists among the varieties ; what effects on ash composition result from the treatments, nitrogen omitted, phosphorus omitted and rain water ; how far varying environmental treatments affect the nature of the results of various nutrient treatments.

EXPERIMENTAL.

MATERIAL.

Three varieties of apple trees, Worcester Pearmain, Bramley's Seedling, and Allington Pippin, were employed in the investigation. All varieties were propagated on Malling Type IX rootstock and were three years from the bud at time of planting in the pots.

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* The work reported in this paper was carried out at the University of Bristol Research Station, Long Ashton, Bristol, by the writer, under the direction of Mr. T. Wallace, during a period of leave of absence from Canada.

The trees were obtained from a local nursery and were selected by the station staff from a large number growing in the nursery as representing the best and most uniform material available.

Previous to the purchase of the trees they had, in their second season, been severely pruned and, as a result, had all made excellent growth in the third year.

At the time of planting in the pots, all trees had about two-thirds of the previous season's growth and all damaged roots removed. In selecting the trees for the different series, each tree was weighed and recorded, and subsequently a selection was made in such a manner that the average weight per tree in each series of a variety was the same. Thus for Bramleys grown in 12 inch pots in sand, the average weight per tree for each series was 404 grams, and for Bramleys in 12 inch pots in soil 403 grams. The Worcester trees in sand averaged 420 grams for all series ; in soil 427 grams for all series. The largest Bramleys were selected for the 20 inch pots and averaged 774 grams, while the Allingtons in 18 inch pots averaged 508 grams.

Whilst the average weight per tree was practically identical in each series of a group, there was naturally considerable variation in the weights of trees within a series and within a variety, but as absolute uniformity is almost impossible of attainment, the above method of distributing the variables appears to be about the best available for taking care of this point.

NUTRIENT TREATMENT GROUPS.

Bramleys were divided into four groups as follows :—

Group I, grown in 12 inch pots in sand and hereafter designated Bramley in sand.

Group II, grown in 12 inch pots in a mixture of sand and soil and identified as Bramley, soil.

Group III, grown in 12 inch pots in sand in a different enclosure from Groups I and II and hereafter called Bramley in 12 inch pots.

Group IV, grown in 20 inch pots in sand and designated as Bramley in large pots or Bramley in 20 inch pots.

The Worcesters were divided into two groups, both grown in 12 inch pots, one in sand and the other in soil and are termed Worcester sand and Worcester soil respectively.

The Allington trees constitute one group only and were grown in 18 inch pots in sand.

Groups I and II of Bramley and both groups of Worcester were grown in the same enclosure and are considered together in this paper under the heading " Worcester and Bramley." Group IV of Bramley and the Allington Group were grown in a different enclosure from the above and are considered together under the heading " Bramley and Allington." Group III of Bramley was grown in the same enclosure as the " Bramley-Allington " groups and will be considered separately and also in connection with the Bramleys in 20 inch pots.

METHODS.

(1) *Cultural.*—The pots employed in this investigation were ordinary clay pots. They were all thoroughly cleaned after which they were heated thoroughly and then dipped into an almost boiling solution of paraffin wax until thoroughly impregnated with this material. This method had been previously found to produce a pot quite equal in imperviousness to a glazed product. Proper drainage was provided and provision made to prevent the fine sand from filtering through the drainage hole.

The sand employed consisted of fine grade silver sand from the Double Arches pit at Leighton Buzzard, Beds. It is a high grade quartz sand, being over 99 per cent. insoluble in boiling hydrochloric acid.

The soil employed in the sand-soil mixture consisted of subsoil taken from an excavation at the Station and is typical of the Keuper Marl subsoil of the area. This was thoroughly pulverized and passed through a quarter-inch mesh sieve, after which it was thoroughly mixed with the sand in the proportion of 80 per cent. sand and 20 per cent. soil.

The planting was carried out during the latter part of February and the month of March, 1928.

After planting, the Bramley and Allington groups and Bramley 12 inch pots were fitted in special wooden boxes which maintained uniformly cool conditions for " soil " and roots. The Worcester-Bramley groups during 1928, both in sand and soil, had the pots covered with tarpaulin covers as illustrated by Wallace (1). During 1929 these groups were fitted as the Bramley and Allington series.

(2) *Feeding.*—The groups selected for a study of the effects of the different omission treatments included the following series of treatments for each variety.

Series.	*Treatment.*
A.	Complete Nutrient solution.
C.	,, ,, ,, less Nitrogen.
D.	,, ,, ,, ,, Potassium.
E.	,, ,, ,, ,, Phosphorus.
F.	,, ,, ,, ,, Calcium.
G.	,, ,, ,, ,, Magnesium.

In addition, the Bramley-Worcester groups both in sand and in soil, included Series H, where only rain water was applied.

The first feeding was given on April 18th, 1928, and thereafter at intervals of from four to fourteen days, depending upon the growth of the trees, the complete nutrient series being used as indices of the requirements. No attempt was made to provide all the moisture required in the form of nutrient solution, but an endeavour was made to maintain uniform and optimum water conditions in all pots by the addition of rain water from time to time.

All trees in a group received exactly the same amounts of nutrient solution and water during the season, with the exception of series C. which, on account of restricted growth was unable to utilize these quantities. Thus, in the 20 inch pots of Bramley, all trees excepting those in series C received 62,500 c.c. of nutrient solution during 1929, and 36,000 c.c. of rain water. In addition, 30,000 c.c. of rain water per pot was used for leaching purposes at intervals of every five feedings. This leaching had been found necessary in earlier work to obtain healthy growth. The C series trees in this group received 53,500 c.c. of nutrient solution, 36,000 c.c. of rain water and 20,000 c.c. of leaching water. The smaller pots were all fed proportionate amounts on the same principle.

NUTRIENT SOLUTIONS.

The nutrient solutions were made up in the same manner employed by Wallace (1), but with slightly varying concentrations in parts per million. The details for solution A will illustrate the method employed :—

Nutrient Solution A—Complete Nutrient Solution.

	grms.
Potassium Nitrate	6.0
Calcium ,, $Ca(NO_3)2$	1.4
,, Sulphate $CaSO_4\ 2H_2O$	2.0
Magnesium ,, $MgSO_4\ 7H_2O$	3.0
Sodium Chloride	0.5
Ferric ,, ...	0.4

The above salts were dissolved and made up to 1 litre with distilled H_2O, then further diluted with 4 litres of rain water before application. To avoid precipitation, upon the addition of phosphate, the phosphate solution was made up separately as follows :—

Di-potassium Mono-hydrogen phosphate ..	1.0 grm.
Distilled H_2O	1 litre.

One litre of this solution was diluted with 4 litres of rain water for application. The concentrations in p.p.m. resulting from the above formulæ are as below :—

Concentration of Nutrient Elements in Solution A.

Nutrient elements.	Grams per Litre.	p.p.m.
N.	1.08	108
K.	2.86	286
Ca.	0.81	81
Mg	0.30	30
Na	0.20	20
Fe	0.14	14
P	0.17	17
S	0.75	75
Cl	0.54	54

From this solution all omission treatments were derived as follows :—

Where calcium, magnesium, or potassium was omitted, the salt (or salts) containing the element in A was replaced by an equivalent amount of the corresponding sodium salt. When nitrogen or phosphorus was omitted the corresponding sulphates were employed. In order that all solutions should have some sodium present, a constant amount of NaCl was used in all solutions. Wallace (1) has previously shown that the rather large amounts of sodium necessitated by some of the formulæ did not produce any pronounced effects, when the above procedure was employed.

CHEMICAL.

The ash analyses cover material for the two years 1928 and 1929. The analyses for 1928 are for prunings of one year twigs only : no attempt was made to separate bark from wood with the 1928 material. For 1929 one year twigs were taken from all trees where available, and, in addition, leaf samples were taken from some series on October 7th.

In the case of Bramley and Allington, the one year twigs for 1929 were separated into bark and wood portions when sufficient material made this possible.

The green weight of all material was taken as soon as harvested. Drying to constant weight was conducted in a steam oven kept at from 90°-100°C., constant weight being obtained generally in about ten days' time.

The ashing and analyses of the ash were made in accordance with the methods employed in the Long Ashton Laboratories.

RESULTS.

FOLIAGE OBSERVATIONS IN GENERAL.

The notes taken on foliage characteristics although only of a qualitative nature revealed outstanding symptoms due to the omission treatments. Whilst these varied in degree in the different groups and with the varieties their nature and character was very consistent throughout. A summary of these symptoms is presented below.

Nitrogen Omission was early evidenced by reduced chlorophyll content, restricted leaf size and early cessation of shoot growth. In late summer the leaves were almost yellow, with numerous red spots scattered over the entire upper surface. Late bud break in the spring of 1929 was very characteristic.

Potassium Omission resulted in the production of dull green coloured foliage, slightly reduced leaf size, accompanied by a slight amount of scorch on smaller leaves and increasing to a considerable extent on larger ones. Reduced shoot growth resulted from continued exposure to this treatment. Early loss of a portion of the foliage took place where rather pronounced deficiency symptoms existed. Later retention of the remaining foliage was very characteristic, accompanied by much earlier bud break in the second spring.

Phosphorus Omission was pronounced in its symptoms, resulting in dull green foliage lacking lustre, followed by purpling and marked bronzing which either occupied a small portion of the leaf or the entire surface area. Wherever the symptoms were at all marked earlier defoliation resulted. The lateness of bud break in 1929 was particularly noticeable.

Calcium Omission exhibited the least visible effect of any treatment given and was characterized by centre blotch or brown patches, similar to those shown by the trees in the magnesium omitted series ; together with edge blotch and breakdown of the marginal areas of the leaf. In mild cases only by a faint marginal browning developed along the entire marginal area of the leaf. In the early stages of this treatment increased leaf size was observed, which was followed by a washed out appearance of the leaf caused by the loss of lustre and to some extent by a suggestion of lack of chlorophyll near the tips. Decreased shoot growth was not observed.

Magnesium Omission was characterized by the prevalence of typical centre blotch or brown patches, high yellowish orange tints in early fall in some instances, and exceedingly early and severe defoliation wherever foliage symptoms were at all pronounced. Little if any restriction of shoot growth was observed.

Total Nutrient Omission resulted in very similar symptoms to those shown by the trees in the nitrogen omitted series. More intense and brilliant red colorations on the leaves served to distinguish this series from the former.

WORCESTER AND BRAMLEY.

Varietal Response.—A certain amount of variation of these two varieties in response to the treatments accorded trees is apparent. *Nitrogen omission* affected both varieties to an equal degree, and was very pronounced in its effects. On the other hand *Potassium omission* had much more pronounced effects on Worcester than on Bramley. This was marked in the first season and in 1929 was very pronounced. Worcester exhibited the greater susceptibility to *Phosphorus omission* in 1928 as judged by bronzing of the foliage. During the second season Bramley was equally as susceptible when judged by these symptoms, so that over the period little difference between these two varieties could be observed.

In the case of *Magnesium omission*, Bramley during the first season showed the more intense symptoms as judged by leaf blotch and earlier defoliation. In 1929 Worcester probably exhibited the more pronounced symptoms so that little difference can be said to exist between the two varieties.

Calcium omission showed the least effects of any treatment given. Whilst the slightly larger leaf in the earlier stages of 1928 was noticeable, it was not until the second year that much effect could be noticed as judged by the characteristic blotch and marginal browning.

Effect of the Soil.—The addition of a small amount of soil to the sand resulted in the absence of any signs of calcium deficiency, as judged by foliage symptoms. Potassium and magnesium deficient symptoms were also greatly reduced by this treatment. Phosphorus omission produced the most marked effects in the soil group, the symptoms being evident the first season and quite marked during 1929.

BRAMLEY AND ALLINGTON.

In the case of these two varieties foliage symptoms and growth features were very similar to those just discussed in connection with Worcester and Bramley. The slight signs of magnesium blotch in series A of Bramley was not sufficiently pronounced and did not appear early enough to more than indicate a slight lack of balance between magnesium and the other elements.

Nitrogen omission in these larger pots produced its characteristic symptoms although the intensity was not quite so pronounced in the early part of the first season as it was in the second year. No difference in the response of the two varieties could be observed.

Bramley and Allington were not very greatly affected the first year by *Potassium omission* but both showed slightly arrested growth, somewhat smaller foliage and a very small amount of leaf scorch in the latter end of the season. In 1929 these same symptoms were observed but scorch was much more pronounced in both varieties and appeared somewhat earlier in the season. Little difference in the two varieties could be observed, although Bramley exhibited a slightly greater amount of early defoliation which took place in the characteristic basipetal manner. The later retention of the remaining foliage was marked in both cases and agrees quite fully with the Bramley-Worcester results.

Phosphorus omission was noticeable in both cases in 1928, giving the same type of symptoms as already recorded for this treatment. In 1929 the symptoms appeared much earlier in both varieties but owing to earlier defoliation, Allington could be selected as the more susceptible variety to this treatment.

The characteristic blotch of *Calcium* and *Magnesium deficient* trees developed to some extent on both varieties where subjected to *Calcium omission*. While this was not at all severe in either season it was nevertheless sufficiently outstanding to serve as a means of distinguishing these series from those in A. The rather large leaf and slightly chlorotic appearance noticed in the smaller pots during the early stages was not so much in evidence ; the marginal browning and blotching being more symptomatic of this treatment in the larger pots.

Allington stands out as being particularly susceptible to *Magnesium omission*. Symptoms on this variety were quite marked the first season and extremely severe during 1929. The very early defoliation of Allington brought about by magnesium deficiency was particularly noticeable in the second year and is worthy of special note.

BRAMLEY—12 INCH POTS.

In general this variety in 12 inch pots behaved parallel in all series to the comparative group in the larger pots. One point which emerged was the noticeably larger leaf area of the calcium omitted series in the early stages of the treatment. This was much more pronounced in the smaller pots than in the larger ones. During the second year this increased growth was not observed. Apart from this particular difference, this group can be considered as behaving quite comparably with the other Bramleys.

At this point it should be noted that the trees in the larger pots did not start growth properly until late in 1928. This was particularly true of Bramley. This was attributed to the rather late planting of these groups. Further reference to this point is made in the general summary.

CHEMICAL DATA.

Table No. I shows the analysis of a representative tree of each variety before being planted in the pots.

Tables Nos. II to V summarize the results of the chemical data for Bramley and Worcester in sand for 1928 and 1929.

Tables Nos. VI and VII summarize these data for those varieties in soil for 1929, no data for 1928 being available for the soil group.

Tables Nos. VIII and IX present the data for Bramley and Allington for 1928 and Tables Nos. X and XI for 1929.

Tables Nos. XII and XIII show the results of these analysis on Bramley in 12 inch pots for 1928 and 1929.

Tables Nos. XIV and XV give the results from the analyses of leaves of certain series, which did not provide sufficient material for chemical examination in 1929.

These tables all show the mineral constituents of the current year's shoot growth expressed as percentages of ash and of dry matter.

DISCUSSION.

CHEMICAL DATA.

BRAMLEY AND WORCESTER.

In discussing the results of the chemical analyses, it would appear desirable to study first the effect of the sand and the soil on the composition of the complete nutrient series.

An examination of Tables Nos. IV, V, VI and VII reveals the outstanding fact that generally in both varieties the intake of potassium has been much less in the soil group than in the sand group. This lower potassium content of the trees in soil is associated with an increase in calcium, as is generally the case in lower potassium trees, these two elements appearing as negatively correlated. The data on leaves for 1929, Tables Nos. IX and X, show exactly the same situation as the one year shoot growth just discussed. As Wallace has repeatedly found it a difficult and slow process to remedy potassium deficiency in the field by applications of soluble potash salts in comparatively large amounts, this is quite in line with present knowledge.

The figures for dry matter, while not displaying anything very consistent, in most cases show a rather marked tendency for the potassium omitted series to be high in percentage of dry matter in fresh weight. On the other hand magnesium omission has had a strong tendency to reduce the percentage of dry matter.

The consistently low ash in dry matter exhibited by the calcium omitted series and the high ash in dry matter shown by the magnesium omitted series are other points of note.

There does not seem to be much significance to the figures for silica, except that Bramley does appear to possess a somewhat higher silica content than Worcester.

From the data on the constituents of ash and dry matter, several facts stand out :—

Nitrogen omission has resulted in a high ratio of CaO to K_2O in the shoots and a low ratio in the leaves. This treatment also appears to have reduced the percentage of MgO and P_2O_5 in ash and dry matter of shoots.

Wherever a mineral element has been omitted, this has been reflected by a decrease of that element in dry matter and nearly always by a decrease in the ash, except in Worcester soil, Series F, 1929. It should be remembered that the trees of this series did not exhibit any marked symptoms of calcium deficiency in their foliage.

The reduction of K_2O in the potassium omitted series has been accompanied by a marked increase in CaO in all cases ; by an increase in MgO in all cases but one (Bramley, 1928) and, in the second year of the treatment, by a fairly consistent increase in P_2O_5 content.

Phosphorous omission has resulted in a reduction in P_2O_5, associated with an increase in CaO in dry matter in all cases but one, Worcester soil, 1929, where an increase in K_2O is observed. For 1928 no other definite trend appears, but in the second year a reduction in K_2O in both varieties in sand and for Bramley in soil, is quite evident.

The reduction of CaO in the *Calcium omitted series* has in all cases but two been associated with an increase in K_2O. In the exceptions, viz. Worcester sand, 1929, and Worcester soil, 1929, a marked increase in MgO is to be noted. At this point it is desirable to point out that Worcester tends to be a low potassium variety even when exposed to a sufficiency of that element, as is evidenced by the figures for the complete nutrient series as compared with Bramley.

The decrease of MgO in the *Magnesium omitted series* is always associated with an increase in CaO, but no other consistent result can be detected. The exceptionally low K_2O content of ash and dry matter in Worcester 1928 shoots and 1929 leaves correlates very well with the pronounced potassium deficient symptoms developed by the foliage of that variety in both years as compared with Bramley.

The marked exhibition by both varieties in soil of phosphorus deficient symptoms can also be associated with the low P_2O_5 content of ash and dry matter of these varieties.

Taking the results for the two years together, there does not appear to be quite as consistent a trend of dry matter in fresh weight as appeared in Bramley and Worcester. The points which seem to emerge are the tendency for potassium omission to result in high dry matter in fresh weight and magnesium omission to show low dry matter in fresh weight. Ash in dry matter does not appear to have been so consistently affected by potassium omission as in the other groups, but calcium omission, as in the other groups, has continued to result in low ash in dry matter and there is on the whole, a distinct tendency for magnesium omission to show high ash in dry matter.

All mineral omission treatments have resulted in a decrease of the omitted element in ash and in dry matter.

Nitrogen omission has again given a high ratio of CaO to K_2O, but the reduction of MgO and P_2O_5 in dry matter and ash is not as consistent as in Bramley and Worcester.

Potassium omission has resulted in a very marked decrease of K_2O in both seasons and this is consistently accompanied by an increase in CaO. In the second year there is in addition a slight increase in P_2O_5 and MgO in both ash and dry matter. No other consistent points emerge.

Phosphorus omission is reflected by a marked decrease of P_2O_5 in ash and dry matter. The final result of the treatment in 1929 reveals an increase in CaO and MgO in dry matter, accompanied by a reduction in K_2O.

The *omission of Calcium* has in both varieties resulted in a decrease of CaO, associated with an increase in K_2O. For 1929 this omission shows an increase in MgO in both ash and dry matter.

It is interesting to note the correlation between the exceptionally low MgO content of Allington and the extreme symptoms of magnesium deficiency exhibited by that variety.

BRAMLEY 12 INCH.

The Bramley 12 inch pots reveal results of a similar character to those already shown for the other Bramleys, but as this will be pointed out in the final discussion for the 1929 results only, it is not necessary to give further details at this point.

MATERIALS AT PLANTING.

Table No. I presents the analyses for a representative tree of each variety before planting. These trees were divided for the purpose of analysis into the following portions. One year shoots ; second and third year wood combined the main stem portion ; and that part of the original rootstock above any lateral roots.

It is to be noted that the trees were all high in CaO and low in K_2O indicating the possibility that they were grown under low potassium conditions in the nursery.

Worcester stands out as the lowest in K_2O in one year shoots, second and third year wood and main stem, and Allington the highest.

A comparison of these data with the analyses for one year shoots after subjection to the treatment in the pots reveals the unexpected fact that in the case of the potassium omitted series, there is a larger percentage of K_2O in dry matter than before the trees were planted. In other words after two years of starvation treatment the analyses show a greater percentage of K_2O in dry matter than before. Whilst this might be accounted for by assuming that the trees had been able to mobilize potassium to the one year shoots, thus drawing on any reserves available, it will remain an unsatisfactory explanation until further work is done. In this connection, however, it is pertinent to observe that Bartholomew and Janssen (4) have experienced the same type of problem in tomatoes, and their remarks on this are extremely interesting. They say, " Data, to be published in the near future, from studies with tomato plants show that the potassium in the plants is very labile. In other words, if there is a deficiency of potassium for normal growth in an embryonic region, sufficient potassium will be translocated from a region of older tissue to permit the plant to function almost normally in the embryonic region. When the deficiency of potassium becomes very great, however, physiological disturbances will be observed in the older regions."

GENERAL DISCUSSION.

From the data presented and the discussion given thus far, it is clearly evident that certain very definite results both of a qualitative character and of a quantitative nature can be correlated with the different treatments given. These results emerge quite completely and are thus of considerable significance. As the data for the second year of treatment should present a truer picture of the ultimate effect of any treatment, it is pertinent in this general discussion to draw the final analysis from the results of that season only.

The late planting, resulting in the late start of many trees and the reserve food materials of the trees at time of planting, must have exercised a considerable effect for the first season in modifying at least the chemical composition of ash and dry matter.

SYMPTOMATIC DIAGNOSIS.

The symptoms presented by the trees subjected to nitrogen, potassium, phosphorus, calcium and magnesium omissions, have in all varieties been found to be of a very consistent nature.

These symptoms were observed to vary in intensity or degree, but not in nature and should therefore be acceptable as of value in symptomatic diagnosis of nutritional disturbances.

As a full description of these symptoms has been given in pages 320-323 it should not be necessary to again present them at this point.

VARIETAL SUSCEPTIBILITY.

There emerges from the examination of the data evidence to show that there is varietal variation in response to the different treatments under the conditions here reported. Worcester showed as particularly susceptible to the omission of potassium, while Bramley appeared as rather resistant. Allington stands out as being particularly susceptible to magnesium omission, but all varieties were markedly affected by this treatment. Allington, Worcester and Bramley were all very adversely affected by an omission of phosphorus, with the first variety undoubtedly the most susceptible.

Calcium omission in the sand groups resulted in evident symptoms but little or no varietal variation could be detected.

Nitrogen omission resulted in very disastrous effects and here again no varietal differences could be observed.

INFLUENCE OF ENVIRONMENT.

That environment has been able to influence the results is fully apparent. The much greater amount of shoot growth of the Bramleys in large pots as compared with those in the smaller pots, is evidence of the influence of restricted feeding area on the ultimate size of the tree even though a sufficiency of moisture and nutrient solutions may be supplied.

In 1928 the marked reduction in the shoot growth of the potassium omitted series of the Bramley sand group in small pots, as compared with the rather excellent growth of the comparative series in the larger pots, can be attributed to the different temperature conditions created by the tarpaulin covers of the sand series for that season.

Mention has already been made that Wallace had found better growth from potassium omitted series where constantly cool conditions such as is approximately obtained under the wooden covers, existed. In this connection Gregory (5) has pointed out that from his investigations in assimilation, low potassium leaves should function better at lower temperatures than high potassium leaves as far as assimilation is concerned.

Further evidence on the effect of environment in influencing potassium deficient symptoms, is evidenced by the marked response of Worcesters to this treatment when grown in pots. Both Worcester and the stock on which it was budded, have been found under field conditions to be seldom affected by low potassium conditions.

The action of the small amount of soil in the soil series in restraining the effects of all the mineral omission treatments, particularly the omission of calcium, may be due to nothing more than the mineral content of the soil itself.

EFFECTS ON MINERAL COMPOSITION OF DRY MATTER.

All treatments have had a marked effect on the mineral composition of the dry matter of the one year shoots and leaves where analysed.

The most pronounced and consistent effect on dry matter was produced by the omission of potassium where in all cases there was a distinct tendency for high dry matter in green weight in one year shoots. Calcium omission showed no consistent effect on percentage of dry matter, but there was a tendency for the omission of magnesium to result in low dry matter in fresh weight. Nitrogen omission in both cases resulted in high dry matter.

On ash, nitrogen had a marked effect, resulting in high ash in dry matter in both instances. Potassium omission gave the above result in four out of the six instances. The two exceptions—Bramley large pots and Bramley 12 inch pots—showed lower ash in dry matter and were more in line with Wallace's findings on this point.

Calcium omission invariably led to low ash in dry matter, whilst magnesium omission in all cases but one resulted in high ash in dry matter. The results from the calcium and magnesium omitted series are in accord with Wallace's work on Stirlings. Garner, McMurtry, Bowling and Moss (6) have found high ash content of magnesium deficient tobacco and marked reduction in carbohydrate content. The latter finding correlates with the low dry matter content recorded here. They concluded that magnesium deficiency interfered with assimilation by causing the breakdown of chlorophyll and that the high ash content was but complementary to the lowered carbohydrate accumulation.

The effect of each treatment on the constituents of dry matter is still more marked. Nitrogen omission invariably resulted in a high ratio of calcium to potassium.

The mineral omissions have always resulted in a distinct reduction in the percentage of the element omitted in dry matter except in one case, Worcester, series F, in soil, where calcium deficient symptoms were hardly noticeable. This reduction of the omitted element is associated with increases in certain others particularly marked and consistent in most cases. Thus, the reduction of potassium was always associated with a marked increase in calcium and magnesium. While the effect on P_2O_5 content was not absolutely consistent, there was in all cases but two a marked increase in P_2O_5 in dry matter. In the two exceptions, one case (Bramley large pots), showed no change, while the other (Bramley 12 inch pots) showed a slight reduction. The decrease of phosphorus in dry matter was always associated with a low K_2O content of dry matter and generally with high CaO.

Low calcium content was always accompanied by a high K_2O figure except in the case of Worcester where a slight reduction was noted in the shoots, but an abnormally high K_2O content of the same series in the leaves resulted. With the exception of Bramley in 12 inch pots, low CaO was always accompanied by high MgO in dry matter and in all cases but Allington, a low P_2O_5 content.

The omission of magnesium, which always resulted in a low MgO content of dry matter, was always associated with an increase in the percentage of CaO, no other definite trend being noticeable.

DEFINITE CORRELATIONS.

The discussion on mineral content of dry matter has so far been based upon a comparison of the deficient series with the complete nutrient series. Whilst such a process should, in general, reveal the true situation, it is apparent that if the conditions for the complete nutrient trees were not absolutely optimum a slight alteration in its chemical composition from that of the normal might affect such comparative data. Or again, some of the apparent correlations between the amount of certain elements present in the ash and dry matter might be an indirect result of some general physiological disturbance and may not be as closely associated with the rise and fall of any particular element as the results from these complete omission treatments reveal. As a further test of the correlations which exist, the data for the ash constituents of all varieties, all treatments, and all years were arranged as correlation tables. This treatment of the data revealed a certain amount of confirmation of the conclusions already presented, and also a certain amount of contradiction. The most outstanding correlation was a very large negative correlation between CaO and K_2O (—.82±.027). There is almost a perfect correlation exhibited here which must be considered as highly significant. The negative association of calcium and potassium has been referred to by other writers. Lipman (8) reporting on the effect of liming shows a lower K_2O content in plants from limed soils than in plants from unlimed areas, whilst Loehwing (7) found a diminution of calcium in the plant following the use of potash on certain soils.

There was a very small positive correlation between magnesium and phosphorus (.08±.0812). Such a small coefficient as this cannot be accepted as being at all significant.

A negative correlation between calcium and phosphorus was also shown (—.215±.078). As the correlation coefficient here is hardly three times its probable error, it hardly meets the requirements of significance. It is nevertheless strongly suggestive of a possible negative correlation between those two elements.

The result of the phosphorus omitted series, it will be revealed, showed such a negative relationship to exist, but in the calcium omitted series a tendency to the reverse condition was noted.

A positive correlation of 0.205±.078 between potassium and phosphorus was found and whilst not acceptable as mathematically significant is also suggestive and is fully corroborated by the results from the phosphorus omitted series but hardly supported by the data from the potassium omitted series.

A marked negative correlation between calcium and magnesium as suggested by the data from the calcium and magnesium omitted series was not supported to any significant or even suggestive degree by a small coefficient of —.0342±.082.

Such negative relationships must be considered, therefore, as a result of rather extreme conditions and not susceptible to minor fluctuations in calcium and magnesium availability.

A small correlation of 0.07±.081 between potassium and magnesium indicates the same situation with regard to these two elements.

RELATIONS BETWEEN SYMPTOMS AND CHEMICAL DATA.

Enough has already been said to suggest some sort of relationship between the mineral composition of dry matter and the symptoms exhibited by the plant.

While it is not possible to place any definite mathematical figure on the qualitative observations on foliage, it is possible to pick out some of the most affected varieties for the purpose of comparing with composition of dry matter.

The following tabular presentation is based on those series which appeared most susceptible to certain treatments, compared with series which showed comparative symptoms in a much less pronounced manner.

Series.	Degree of potassium deficient symptoms exhibited.	Percentage of K_2O in dry matter.
Worcester sand	Marked	0.6583
Worcester soil	Slight	0.9847
Bramley sand	Fairly pronounced	0.6230
Bramley soil	Only very slight	0.8880
Bramley 20" pots ..	Pronounced	0.5821
Allington 20" pots ..	Only moderately pronounced	0.7973

Series.	Degree of magnesium deficient symptoms exhibited.	Percentage of MgO in dry matter.
Allington	Very marked	0.1219
Bramley 20" pots ..	Only moderately marked	0.1479
Bramley sand	Marked	0.1152
Bramley soil	Slight	0.1517

Series.	Degree of phosphorus deficient symptoms.	Percentage of P_2O_5 in dry matter.
Bramley soil	Slight	0.1791
Bramley sand	Quite pronounced	0.1726
Worcester soil	Slight	0.2010
Worcester sand	Quite pronounced	0.1925

It is very evident from these data that whilst the symptomatic diagnosis is only qualitative, the degree of intensity does on the whole bear some relation to the amount of the deficient element found in dry matter. Garner, McMurtry, Bowling and Moss (6) have found a somewhat similar situation in tobacco grown on soils of different magnesium content.

It has been pointed out that all omission treatments generally resulted in a decrease of the omitted element in ash and in dry matter. In this connection it is desirable to note the gradients of the omitted elements when compared with series A.

For this purpose the following table presents this comparative data for the three varieties when grown in sand. These data are comparisons of the amount of the omitted element contained in the dry matter of trees subjected to the corresponding omission treatment, expressed as a percentage of the amount of the respective elements in the dry matter of the complete nutrient series for the year concerned.

Whilst in most cases there is a downward trend of the omitted element, there are three instances where this is not so, viz. Worcester, calcium omitted; Bramley, magnesium omitted; and Allington, phosphorus omitted.

In Worcester, the calcium omitted series in 1929 shows a higher percentage of CaO in dry matter than it did in 1928, due to a higher figure for ash in dry weight. In Bramley, the complete nutrient series for 1929 shows a lower percentage of MgO than in 1928; and in Allington the same situation exists with respect to P_2O_5.

Treatment.	Group.		Percentage of omitted element in omitted series expressed as percentage of series A.
Calcium Omitted	Bramley 20"	1928	74·35
Calcium Omitted	Bramley 20"	1929	64·79
Calcium Omitted	Worcester	1928	94·73
Calcium Omitted	Worcester	1929	96·25
Calcium Omitted	Allington	1928	65·13
Calcium Omitted	Allington	1929	58·76
Magnesium Omitted ..	Bramley 20"	1928	51·39
Magnesium Omitted ..	Bramley 20"	1929	79·27
Magnesium Omitted ..	Worcester	1928	72·73
Magnesium Omitted ..	Worcester	1929	57·44
Magnesium Omitted ..	Allington	1928	89·95
Magnesium Omitted ..	Allington	1929	69·28
Phosphorus Omitted ..	Bramley 20"	1928	85·23
Phosphorus Omitted ..	Bramley 20"	1929	54·71
Phosphorus Omitted ..	Worcester	1928	71·03
Phosphorus Omitted ..	Worcester	1929	49·42
Phosphorus Omitted ..	Allington	1928	68·50
Phosphorus Omitted ..	Allington	1929	80·34
Potassium Omitted ..	Bramley 20"	1928	82·28
Potassium Omitted ..	Bramley 20"	1929	40·35
Potassium Omitted ..	Worcester	1928	42·63
Potassium Omitted ..	Worcester	1929	—
Potassium Omitted ..	Allington	1928	75·83
Potassium Omitted ..	Allington	1929	68·42

CONCLUSIONS.

In a series of experiments in which apple trees of the varieties Bramley Seedling, Worcester Pearmain and Allington Pippin were grown under controlled conditions in pots in sand, and sand-soil mixture, and given differential nutritional treatments including certain mineral deficiencies. The following conclusions were drawn :—

1. The treatments all produced significant effects on the growth features and chemical composition of the trees.

2. Nitrogen omission was characterized by restricted shoot growth, yellowed leaves and delayed bud break in spring. Potassium omission was associated with restricted shoot growth in some cases and increased shoot growth in others, a certain amount of early defoliation, later retention of remaining foliage, leaf scorch and much earlier bud break in spring. Phosphorus omission produced earlier defoliation, very restricted shoot growth in some cases, typical bronzing of the foliage and delayed bud break in spring. Calcium omission produced increased shoot growth and larger leaves in the early stages, breakdown of leaf tissue either near the centre or along the margins, in the form of brown patches or blotches. Magnesium omission was characterized by reduced shoot growth in most cases, earlier defoliation and marked breakdown of foliage as centre and marginal blotching similar to calcium omission symptoms.

3. Varietal variation in responding to the various treatments was evidenced as judged by growth features. Worcester was particularly susceptible to potassium omission and Allington to magnesium and phosphorus omission.

4. The size of pot used influenced the amount of total growth per tree to a marked degree.

5. The type of protection or cover used on the pots markedly influenced the effects of the potassium omitted series. Wooden covers maintaining a constantly cool soil condition gave greater shoot growth in this series as compared with higher temperature conditions of pots under tarpaulins.

6. The influence of a small amount of subsoil was marked by a decrease in potassium intake of the trees, and a marked diminution of the calcium and magnesium deficient symptoms.

7. All omission treatments were reflected in the composition of ash and dry matter of one year shoots and leaves for the first season. Nitrogen omission resulted in high dry matter in fresh weight ; potassium omission showed high dry matter ; magnesium omission low dry matter in fresh weight. Nitrogen omission gave high ash in dry matter ; potassium omission tended to high ash in dry matter in most cases ; calcium omission always gave low ash in dry matter ; magnesium omission gave high ash in dry matter. Reductions of K_2O,

P_2O_5, CaO and MgO in ash and in dry matter were usually effected where these elements were omitted. Low K_2O was associated with high CaO and high MgO ; low P_2O_5 was accompanied by low K_2O and high CaO. Low CaO was associated with high K_2O, high MgO and low P_2O_5. Low MgO was accompanied by high CaO.

8. Correlation tables on the percentage constituents of ash showed significant correlation coefficients to exist between certain elements ; a highly significant negative correlation between K_2O and CaO was shown : a negative correlation of possible significance was found to exist between CaO and P_2O_5 and a positive correlation between P_2O_5 and K_2O.

9. The intensity of the symptoms exhibited by the varieties as judged by growth features is generally correlated with the amount of the element concerned in dry matter as determined by analysis.

10. The longer the trees were subjected to the omission treatment, the lower was the percentage of the related element in dry matter in most cases.

SUMMARY.

1. Apple trees of the varieties Bramley Seedling, Worcester Pearmain and Allington Pippin were grown in pots in quartz sand under the following nutrient treatments: complete nutrient, nitrogen omitted, potassium omitted, phosphorus omitted, calcium omitted and magnesium omitted.

2. Worcester and Bramley were also grown in a mixture of subsoil and sand under the above treatments.

3. In the case of Worcester and Bramley an additional series, fed only on rain water, was added.

4. Data were obtained relating to the effect of the various treatments on growth characters, showing the prevalence of symptoms of diagnostic value.

5. Varietal variation in responding to the different omission treatment was shown to exist.

6. The influence of root environment particularly in the case of potassium omission was shown to affect the growth results of the treatment.

7. The small amount of subsoil added to the sand in certain groups had a marked influence in reducing the characteristic symptoms of all treatments, particularly in the case of calcium and magnesium omissions.

8. Chemical analyses of the ash of one year old shoots and leaves, are presented and reveal marked influences on the composition of ash and dry matter due to the various treatments.

9. Calcium omission resulted in low ash in dry matter and magnesium omission in high ash in dry matter.

10. The omission of an element was reflected by a low percentage of that element in ash and in dry matter.

11. The reduction of K_2O was associated with increases of CaO and MgO ; low CaO was accompanied by high K_2O, high MgO and low P_2O_5 ; low MgO was always associated with high CaO, low P_2O_5 with low K_2O and generally high CaO.

12. The small amount of subsoil in the sand-soil mixtures markedly reduced the intake of K_2O by the trees.

13. The arrangement of the chemical data on correlation tables showed negative correlations to exist between CaO and K_2O ; CaO and P_2O_5 ; and a positive correlation between K_2O and P_2O_5.

14. A high degree of correlation between the symptoms exhibited and the amount of the related element in ash and in dry matter was shown.

15. The length of time the trees were subjected to the various omission treatments are reflected in the composition of dry matter.

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TABLE I.

Showing Composition of different parts of representative trees of Allington, Bramley and Worcester prior to planting.

Material.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Allington 1 year shoots ..	77.70	39.00	50.19	3.39	4.60	36.59	2.18	16.30	7.20	1.2400	0.0739	0.5538	0.2445
Allington 2nd and 3rd year growth	350.60	166.30	47.43	3.13	3.39	36.63	3.38	16.39	5.23	1.1440	0.1056	0.5116	0.1632
Allington Main Stem ..	277.00	134.10	48.37	2.89	4.16	43.54	3.42	12.67	4.44	1.2560	0.0988	0.3657	0.1280
Allington Rootstock ..	269.00	125.50	46.65	4.62	31.25	34.49	1.54	5.87	3.93	1.5930	0.0728	0.2711	0.1812
Bramley 1 year shoots ..	102.20	52.80	51.66	4.31	2.99	40.74	2.41	13.76	5.71	1.7560	0.1037	0.5928	0.2460
Bramley 2nd and 3rd year growth	506.20	266.80	52.70	3.11	4.27	35.67	2.50	12.67	5.31	1.1090	0.7770	0.3941	0.1653
Bramley Main Stem ..	341.50	190.30	55.73	2.85	3.30	46.29	2.29	12.38	4.73	1.3170	0.06509	0.3522	0.1345
Bramley Rootstock ..	213.10	107.40	50.36	5.47	6.12	49.28	1.76	7.52	4.89	2.6980	0.0965	0.4116	0.2675
Worcester 1 year shoots ..	127.20	66.40	52.20	4.26	2.30	43.02	3.05	10.22	6.90	1.8330	0.1302	0.4354	0.2934
Worcester 2nd and 3rd year growth	323.30	173.00	53.56	3.75	3.27	40.87	2.27	9.12	4.84	1.5680	0.0849	0.3422	0.1812
Worcester Main Stem ..	311.50	171.60	55.09	3.18	3.67	44.67	1.91	9.62	4.23	1.4180	0.0604	0.2612	0.1343
Worcester Rootstock ..	170.00	87.90	51.71	4.66	9.55	48.27	1.92	6.14	6.52	2.2480	0.0895	0.2864	0.3038

TABLE II.

Bramley—Sand Series, 1928. *One year old twigs, barks and wood.*

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Complete Nutrient	56.29	26.16	46.47	4.16	4.70	22.59	5.65	26.27	7.25	0.9380	0.2344	1.0810	0.3010
Nitrogen Omitted ..	13.63	6.33	46.44	4.70	3.50	33.27	4.21	23.29	5.90	1.5570	0.1978	1.1260	0.2429
Potassium Omitted ..	19.61	9.63	49.10	4.82	2.46	37.82	4.27	**13.21**	6.20	1.7800	0.1932	**0.6540**	0.2998
Phosphorus Omitted ..	36.18	16.91	46.74	4.70	1.74	25.43	4.91	24.20	**4.65**	1.9940	0.2300	1.1360	**0.2182**
Calcium Omitted	55.14	25.41	47.73	3.75	1.85	**23.09**	5.89	30.38	7.08	**0.8666**	0.2211	1.1400	0.2657
Magnesium Omitted ..	49.56	22.33	44.96	5.15	1.69	26.62	**3.23**	25.00	6.23	1.3830	**0.1677**	1.2870	0.3210
Rain Water Only	16.85	8.36	49.62	4.06	4.24	36.57	9.62	12.22	6.40	1.4860	0.3911	0.4964	0.1660

TABLE III.

Worcester—Sand Series, 1928. *One year old twigs, bark and wood.*

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Complete Nutrient	48.19	22.43	46.54	4.57	1.90	25.49	5.63	23.53	8.23	1.1640	0.2574	1.0740	0.3764
Nitrogen Omitted ..	17.61	8.11	46.06	4.79	2.00	32.25	4.46	17.86	3.91	1.5470	0.2133	1.3610	0.1877
Potassium Omitted ..	23.21	11.58	49.89	5.11	1.59	36.48	10.52	**8.98**	5.58	1.8630	0.5375	**0.4584**	0.2176
Phosphorus Omitted ..	38.63	18.40	47.63	4.74	1.15	30.52	5.29	23.42	**5.64**	1.4450	0.2505	1.1090	**0.2674**
Calcium Omitted	39.81	18.28	45.92	4.05	1.37	**27.25**	6.61	27.64	9.71	**1.1040**	0.2836	1.1070	0.3890
Magnesium Omitted ..	34.61	16.27	47.00	4.82	1.53	29.25	**3.86**	22.56	7.77	1.4100	**0.1860**	1.0870	0.3745
Rain Water Only	18.03	9.01	49.98	4.60	1.83	37.47	8.16	9.91	5.18	1.7240	0.3751	0.4556	0.2380

TABLE IV.

Bramley—Sand Series, 1929. *One year old twigs, bark and wood.*

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Complete Nutrient	121.001	52.945	43.76	4.24	2.03	27.20	5.26	26.68	8.15	1.1530	0.2230	1.1310	0.3455
Potassium Omitted ..	29.868	13.611	45.56	5.50	1.12	40.46	5.59	**9.32**	7.08	2.2240	0.3372	**0.6230**	0.3990
Phosphorus Omitted ..	44.897	19.819	44.15	4.51	1.82	27.80	4.09	22.59	**3.88**	1.2360	0.1817	1.0040	**0.1726**
Calcium Omitted	85.476	36.485	42.69	4.18	2.37	**14.99**	5.76	33.90	6.77	**0.6255**	0.2354	1.7980	0.2828
Magnesium Omitted ..	46.420	18.912	40.74	6.14	1.46	31.84	**1.50**	18.91	5.33	1.9530	**0.1152**	1.0920	0.3268

TABLE V.

Worcester—Sand Series, 1929. *One year old twigs, bark and wood.*

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Complete Nutrient	94.327	43.117	45.72	4.66	1.74	27.56	5.45	23.69	8.36	1.2830	0.2540	1.1040	0.3895
Potassium Omitted ..	2.582	1.265	49.00	Not sufficient growth to analyse									
Phosphorus Omitted ..	26.416	12.621	47.73	4.99	2.32	36.22	5.94	15.90	**3.86**	1.8070	0.2963	0.7950	**0.1925**
Calcium Omitted	51.860	23.854	45.99	4.56	1.16	**27.13**	8.09	22.37	6.93	**1.2370**	0.3681	1.0130	0.3157
Magnesium Omitted ..	49.484	21.176	42.81	5.83	1.54	34.68	**3.15**	19.02	6.46	2.0270	**0.1837**	1.0280	0.3767

TABLE VI.

Bramley—Soil Series, 1929. *One year old twigs, bark and wood.*

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Complete Nutrient	83.105	38.684	46.54	4.90	1.52	32.51	3.40	18.58	7.35	1.6250	0.1715	0.9276	0.3676
Potassium Omitted ..	116.019	47.115	41.57	5.76	1.27	34.74	4.35	**15.40**	7.51	2.0030	0.2507	0.8880	0.4329
Phosphorus Omitted ..	76.459	36.828	48.16	5.46	1.40	38.15	3.58	15.74	**3.28**	2.0820	0.1954	0.8590	**0.1791**
Calcium Omitted	131.028	62.501	47.71	4.23	1.25	**28.92**	3.67	22.96	5.79	**1.1990**	0.1522	1.4860	0.2400
Magnesium Omitted ..	135.818	64.632	47.58	5.38	1.12	33.56	**2.82**	18.00	6.77	1.8050	**0.1517**	0.9685	0.3644

TABLE VII.

Worcester—Soil Series, 1929. *One year old twigs, bark and wood.*

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Complete Nutrient	92.464	49.472	48.09	5.62	0.72	35.59	3.46	14.84	8.92	1.9950	0.1943	0.8337	0.5012
Potassium Omitted ..	58.864	28.695	48.76	5.74	0.75	37.95	3.50	**11.15**	6.52	2.1800	0.2006	**0.5084**	0.3742
Phosphorus Omitted ..	57.022	28.050	49.19	5.38	0.88	36.45	3.34	18.38	**3.74**	1.9650	0.3797	0.9883	**0.2010**
Calcium Omitted	85.262	41.510	48.68	5.57	0.98	**37.47**	4.61	13.82	9.27	**2.0880**	0.2566	0.7703	0.2819
Magnesium Omitted ..	81.259	39.751	48.91	6.07	1.06	35.84	**2.63**	15.10	6.72	2.1740	**0.1595**	0.9156	0.4076

TABLE VIII.

Bramley—Large Pots, 1928. *One year shoots, bark and wood.*

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Complete Nutrient	116.70	50.88	44.62	5.02	6.6	25.17	6.96	22.03	6.40	1.2340	0.3489	1.1040	0.3209
Nitrogen Omitted ..	22.50	10.34	45.95	6.31	10.08	38.74	5.59	16.70	4.96	2.4450	0.3527	1.0540	0.3133
Potassium Omitted ..	181.01	80.93	44.70	4.76	2.37	30.66	6.03	**16.44**	6.82	1.4930	0.2872	**0.7645**	0.3247
Phosphorus Omitted ..	101.49	45.93	45.25	5.16	2.49	26.31	4.97	21.94	**5.30**	1.2290	0.2564	1.1320	**0.2735**
Calcium Omitted	178.26	77.10	43.28	4.35	4.73	**21.13**	7.30	27.59	7.78	**0.9173**	0.3167	1.1980	0.3378
Magnesium Omitted ..	169.78	72.80	42.87	5.02	2.51	24.49	**3.57**	24.35	7.06	1.2280	**0.1793**	1.2220	0.3538

TABLE IX.

Allington—Large Pots, 1928. *One year shoots, bark and wood.*

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Complete Nutrient	240.10	103.31	43.47	4.27	2.04	26.10	3.20	28.81	7.08	1.1140	0.1366	1.2300	0.3023
Nitrogen Omitted ..	43.87	20.87	47.57	4.53	3.38	25.16	3.53	20.84	6.10	1.1400	0.1600	0.9454	0.2768
Potassium Omitted ..	236.62	107.42	45.41	4.12	4.97	27.42	4.00	**22.67**	4.79	1.1300	0.1648	**0.9344**	0.1974
Phosphorus Omitted ..	104.93	48.70	46.41	4.65	1.83	21.18	3.76	25.39	**4.46**	0.9832	0.1788	1.1790	**0.2070**
Calcium Omitted	153.03	67.30	42.50	4.29	3.68	**17.12**	4.43	32.91	8.80	**0.7254**	0.1877	1.3950	0.3734
Magnesium Omitted ..	169.12	71.97	43.97	4.73	1.50	24.19	**2.68**	27.56	7.26	1.1090	**0.1228**	1.2630	0.3330

TABLE X.

Bramley—Large Pots, 1929. *One year shoots, bark and wood.*

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Complete Nutrient	233.299	107.318	45.98	4.15	1.86	22.39	4.50	27.61	7.71	0.9292	0.1866	1.1460	0.3204
Nitrogen Omitted ..	13.593	6.191	47.41	7.80	2.27	36.85	2.83	12.10	4.13	2.8740	0.2210	0.9432	0.3221
Potassium Omitted ..	194.108	90.06	46.36	3.78	1.47	29.78	6.66	**15.44**	8.92	1.1230	0.2513	**0.5821**	0.3362
Phosphorus Omitted ..	104.678	51.331	49.04	3.83	2.14	25.64	7.56	24.19	**4.58**	0.9811	0.2892	0.9475	**0.1753**
Calcium Omitted	222.735	101.366	44.67	3.82	1.97	**15.79**	7.61	31.21	7.13	**0.6020**	0.2909	1.1910	0.2719
Magnesium Omitted ..	196.283	86.654	44.14	3.60	1.86	22.95	**3.27**	26.53	7.37	1.0390	**0.1479**	1.2000	0.2642

TABLE XI.

Allington—Large Pots, 1929. One year shoots, bark and wood.

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Complete Nutrient	169.249	79.437	46.91	3.80	1.755	22.77	4.63	30.65	6.16	0.9712	0.1759	1.1650	0.2342
Nitrogen Omitted ..	9.330	4.334	45.37	5.18	3.53	33.53	4.59	15.63	6.79	2.1900	0.2993	1.0190	0.4430
Potassium Omitted ..	133.812	64.229	47.98	4.06	1.69	31.69	5.20	**19.64**	8.42	1.2850	0.2110	**0.7973**	0.3432
Phosphorus Omitted ..	25.440	11.804	46.38	4.65	2.73	30.12	4.46	22.30	**4.05**	1.4020	0.2075	1.1100	**0.1881**
Calcium Omitted	179.665	83.148	46.27	3.68	2.19	**15.52**	5.93	34.89	6.97	**0.5707**	0.2183	1.2820	0.2564
Magnesium Omitted ..	134.680	57.907	42.99	4.97	1.63	27.27	**2.45**	24.61	6.91	1.3520	**0.1219**	1.2230	0.3430

TABLE XII.

Bramley—12 inch Pots, 1928. One year shoots, bark and wood.

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Complete Nutrient	44.660	20.02	44.82	4.98	1.57	25.23	4.77	21.86	7.65	1.2550	0.2375	1.0870	0.3806
Nitrogen Omitted ..	17.390	8.60	49.46	4.20	6.64	33.67	5.58	16.59	5.30	1.4130	0.2345	0.6958	0.2786
Potassium Omitted ..	36.470	17.40	47.71	5.12	2.44	37.40	5.33	**13.36**	7.17	1.9160	0.2733	**0.6844**	0.3673
Phosphorus Omitted ..	36.480	16.72	45.82	5.00	3.00	30.06	4.83	22.61	**5.36**	1.5040	0.2415	1.1310	**0.3376**
Calcium Omitted	47.430	21.10	44.30	4.58	2.42	**26.42**	6.26	25.77	7.60	**1.212**	0.2867	1.1850	0.3483
Magnesium Omitted ..	42.610	19.35	42.61	4.86	2.49	28.70	**3.67**	22.14	7.79	1.3920	**0.1782**	1.1260	0.3784

TABLE XIII.

Bramley—12 inch Pots, 1929. One year shoots, barks and wood.

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Complete Nutrient	62.839	26.900	42.81	5.53	2.43	27.77	4.94	18.87	7.13	1.5350	0.2732	1.0430	0.3937
Potassium Omitted ..	62.735	30.254	48.20	5.18	1.67	40.62	6.00	**11.73**	7.00	1.6700	0.3091	**0.6073**	0.3624
Phosphorus Omitted ..	53.585	24.854	46.37	4.14	2.53	24.51	5.05	23.83	**4.18**	1.0110	0.2086	0.9833	**0.1726**
Calcium Omitted	82.952	37.034	44.63	4.36	2.91	**21.58**	6.06	24.95	7.68	**0.9419**	0.2646	1.0880	0.3355
Magnesium Omitted ..	40.519	17.848	44.04	5.80	2.41	31.11	**2.74**	19.70	6.93	1.8050	**0.1590**	1.1440	0.4017

TABLE XIV.

Composition of Leaves of Bramley, from Sand and Soil Series. Taken October 7th, 1929.

Pt. I. *Bramley*—Soil.

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Complete Nutrient	76.934	29.456	38.29	8.56	1.26	23.90	3.66	30.75	3.55	2.0460	0.3130	2.6320	0.3035
Nitrogen Omitted ..	51.878	17.048	32.86	9.42	1.62	17.22	3.05	35.21	6.62	1.6250	0.2875	3.3230	0.6247
Potassium Omitted ..	58.835	22.919	39.63	7.27	1.69	34.16	6.73	**11.53**	6.91	2.4830	0.6160	**0.8385**	0.5025

Pt. II. *Bramley*—Sand.

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
Complete Nutrient	106.920	39.164	36.63	7.58	0.89	14.51	2.40	39.18	3.94	1.1000	0.1807	2.9700	0.2987
Nitrogen Omitted ..	64.899	22.609	34.83	8.46	1.49	13.81	3.09	36.59	5.18	1.1680	0.2675	3.0950	0.5520
Potassium Omitted ..	80.366	31.554	39.25	6.41	2.17	29.02	9.68	**12.28**	7.24	1.8610	0.6209	**0.7870**	0.4639

TABLE XV.

Composition of Leaves of Worcester, from Sand and Soil Series. Taken October 7th, 1929.

Pt. I. *Worcester.* Soil.

Treatment.	Fresh wt. in grms.	Dry wt. in grms.	Dry Matter in fresh wt.	Ash in Dry Matter	Ash Constituents as % Ash.					Ash Constituents as % Dry Matter.			
					SiO_2	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
			%	%									
Complete Nutrient	82.720	32.593	39.41	10.47	0.90	27.06	4.90	19.33	7.56	2.8340	0.5128	2.0250	0.7916
Nitrogen Omitted ..	27.954	10.197	36.50	9.50	1.71	19.62	10.11	28.08	9.24	1.5840	0.9603	2.6990	0.8794
Potassium Omitted ..	51.868	20.895	40.29	7.55	1.88	33.16	7.86	13.05	8.39	2.5030	0.4713	0.9847	0.6476

Pt. II. *Worcester.* Sand.

Complete Nutrient	72.990	26.465	36.26	8.49	1.23	14.39	3.08	43.61	4.21	1.0850	0.2673	3.0701	0.3571
Nitrogen Omitted ..	66.374	23.714	36.72	9.27	2.11	13.53	2.23	39.77	6.27	1.2550	0.2066	3.6890	0.5821
Potassium Omitted ..	62.528	23.255	37.14	9.10	1.09	36.53	11.41	7.24	6.41	2.3150	1.0400	0.6583	0.5842

BOOK REVIEW.

FUNGOUS DISEASES OF PLANTS IN AGRICULTURE, HORTICULTURE, AND FORESTRY.

By Dr. Jakob Eriksson. 2nd Edition. Translated from the German by William Goodwin, M.Sc., Ph.D. London. 1930.

Dr. Goodwin has conferred a boon on British plant pathologists, and all others who are interested in cultivated crops in health and disease, by translating into English Dr. Eriksson's book on plant diseases. The author is an eminent Swedish professor, well-known for his own work on a number of plant diseases and also as the originator of the " Mycoplasm Theory." Reference to this theory, which however is not generally accepted by botanists, will be found under several of the diseases described. Professor Eriksson's complete work, " Die Pilzkrankheiten der Kulturgewächse " comprises two parts. The first part " Die Pilzkrankheiten der landwirtschaftlichen Kulturgewächse " was translated into English and published as " Fungoid Diseases of Agricultural Plants " in 1929. The second part, " Die Pilzkrankheiten der Garten- und Parkgewächse " was published in 1928 and has not previously been translated into English. The two parts have been arranged to form one volume under the title given above.

As stated in the preface, " This volume presents a general review of the more important fungous diseases which occur in Northern and Mid-Europe on field and garden crops and on certain trees of economic and ornamental value." There is no other book in the English language that covers this field so thoroughly and for that reason this volume serves as an encyclopedic reference book on plant diseases. The scope of the book may be gathered from the fact that in the host index 348 plants are mentioned. There are 399 illustrations, including three coloured plates ; most of these figures are well executed and clear, but some show little or no detail.

There is a tendency, which is but natural, for certain diseases, on which the author himself has carried out investigations, to be treated in detail while some important diseases have been treated only too briefly. Thus the agriculturist will find good descriptions of the rusts and smuts of cereals, the three coloured plates illustrating cereal rusts. The author's own work on Hollyhock Rust is described in seven and a half pages with five figures. Pomologists however will be disappointed in the treatment of some of the major diseases of fruit trees and bushes. The Silver Leaf Disease is dismissed in twelve lines including a statement that " the disease spreads from the infected root through the whole plant," thus giving an erroneous impression of the way in which infection takes place. In the description of Apple Scab no mention is made of infection of the young shoots, a serious omission since such shoots form sources of infection during the following season ; Bordeaux mixture is the only spray recommended for this disease although its use is unsafe on some varieties of apples. There is no mention of the rôle that the scab lesions sometimes play in allowing entry to the canker fungus, or of canker infection through leaf scars. On pages 389 to 393 it is assumed that Blossom Wilt of apple trees is caused by *Sclerotinia fructigena* the common brown rot fungus of the ripening fruit. Apple Blossom Wilt is caused not by *S. fructigena* but by a form of *S. cinerea*. The description of Currant Rust occupies six pages and is illustrated by five figures, while the Black Currant Leaf Spot, a disease which is far more troublesome in this country, is described in three and a half lines with one poor illustration.

The " virus " diseases of plants are treated briefly in a chapter entitled " Diseases not fully investigated." Some important diseases which should have been included here, e.g., Tomato Mosaic, Raspberry Mosaic, and " Reversion " in black currants, are not mentioned.

In spite of such faults the book contains much useful information which is not available elsewhere in any single volume and all who are concerned with the cultivation of the field, forest, orchard or garden should have this book at hand for ready reference.

H.W.

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